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The Effect of 2-Methyl-1,4-Naphthoquinone on The Incidence of Dental Caries. *D. V. Burrill, J. C. Calandra, E. B. Tilden* and *L. S. Fosdick* (Northwestern University) ..... 273

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# THE EFFECT OF 2-METHYL-1,4-NAPHTHOQUINONE ON THE INCIDENCE OF DENTAL CARIES[1]

D. Y. BURRILL, J. C. CALANDRA, E. B. TILDEN AND L. S. FOSDICK

*From the Clinics and Laboratories of Northwestern University Dental School*

In 1943 it was suggested that the production of dental caries depends upon first, the rate of acid formation in the mouth, and second, the rate of neutralization of acid in the regions associated with the caries susceptible portions of the teeth (1). On this basis dental caries should be retarded by a decrease in the rate of acid formation or an increase in the rate of acid neutralization.

Most of the successful methods of controlling caries have worked by decreasing the rate of acid formation. This is natural, because the rate of acid neutralization is controlled by many factors which at present cannot be materially changed (1). Probably the most successful experimental control of the rate of acid formation, with subsequent decrease in caries activity, has been accomplished by the reduction of fermentable sugars and carbohydrates in the diet (2, 3, 4), or by their elimination from the mouth through oral hygiene (5). These methods of caries control, however, depend entirely upon the cooperation of the patient. This cooperation cannot be expected of large masses of population.

Another way of reducing the rate of acid formation is by interfering with the enzyme or co-enzyme systems which are necessary for acid production. Several agents may be used, some of which have been tried experimentally and some clinically. Iodoacetic acid has been tried experimentally with rats (6). It is probably too toxic for human use. A 30% urea solution (7), used as a mouthwash, acts as a protein denaturant, destroying the enzymes and hence preventing acid formation. A urea quinine mouth rinse has also proved successful (8). Ammoniacal silver nitrate reduced on the susceptible surfaces of the teeth leaves a deposit of colloidal metal which presumably retards fermentation (9).

The enzyme inhibitor which has had the most wide-spread study and experimental use is the fluoride ion (10). This ion inhibits the hydrolysis of phosphoric esters and hence retards acid formation. Furthermore, the fluoride ion is absorbed by the dental enamel, forming a compound less soluble than unchanged enamel. Probably both actions are responsible for the success of fluorides in controlling or preventing caries.

In 1942 (11, 12), it was found that synthetic vitamin K (2-methyl-1,4-naphthoquinone), when added in minute quantities to saliva-glucose mixtures, in vitro, would prevent the formation of significant amounts of acid. There was no evidence that its action as an enzyme inhibitor was closely associated with the vitamin activity. Preliminary experiments indicated that the material would

[1] This work was done under a grant from the Good Teeth Council for Children. Received for publication October 18, 1945.

not stay in the mouth for long periods of time, and hence to be effective must be dispersed throughout the mouth during the critical period of rapid acid formation. It appeared that the ideal method of administration would be through the use of chewing gum. With gum as the vehicle it would be possible to administer the inhibitor without inconvenience immediately after the ingestion of food. Furthermore, the force of mastication would drive the inhibiting material into regions associated with susceptible areas of the teeth. Experimentally, there was a further advantage in the use of gum, since the gum would contain a fermentable sugar in addition to the inhibitor, so that the test of the inhibitor would be more severe.

## EXPERIMENTAL PROCEDURE

The details of the experiment were planned well ahead of the time set for the actual start. During the preliminary period, adequate toxicity tests were made on the 2-methyl-1,4-naphthoquinone and the sodium bisulphite addition complex.[2] Salivary *Lactobacillus acidophilus* counts (13) and chemical caries susceptibility tests (14) were made for each student in the Freshman and Sophomore classes at Northwestern University Dental School. Interproximal and periapical radiographs and a clinical mouth examination were made for each student. From this group, 119 subjects were selected, each of whom showed more than average susceptibility to caries, and had at least 12 unfilled proximal tooth surfaces in positions where decay was likely to occur. Each subject had an average lactobacillus count of 50,000 or more and a 2 plus or greater chemical susceptibility.

The initial dental condition of each subject was recorded in the usual manner (15) on a mouth chart on the basis of both the clinical examination and the radiographs. The radiographs were kept for comparison with later ones. Before the beginning of the experiment the subjects were instructed to have filled all occlusal, buccal, labial and lingual cavities, and all proximal cavities which were deep or the progress of which could not be observed by means of radiographs. While the restorations were being placed, blood examinations were done and further bacteriological and chemical tests for caries susceptibility were made, with tests on 2 successive days at intervals of 2 weeks. As no changes in caries activity were found after the placing of fillings, some subjects were allowed to start the experiment before all prescribed operative work was finished. During the course of the experiment, bacteriological and chemical tests were done for each subject every 4 weeks. At the same time, gross and differential blood counts and clotting time determinations were made for each subject.

The 119 subjects were divided into 2 groups as nearly identical as possible in regard to caries activity. All subjects were instructed to refrain from eating between meals and to chew 1 pellet of gum for 10 or more minutes immediately after each meal. After 2 months use of the gum, during which time no changes in the blood were observed, the subjects were allowed to eat between meals, pro-

[2] Hatton, E. H., Dodds, A., Hodge, H. C., 3rd, Fosdick, L. S., *J. D. Res.*, **21**: 283, 1945 (this issue).

vided they used the gum as directed immediately after eating. No attempt was made to control the type or amount of food.

The gum given to one group of 55 subjects was a regular commercial product. That given to the other group of 64 subjects was the same product, except that in each pellet there was 0.75 mg. of the 2-methyl-1,4-naphthoquinone-sodium bisulphite addition compound. The compound could not be detected in the flavor of the gum, and neither the subjects nor the persons charged with determining the caries results knew until after the end of the experiment which type of gum any particular subject had been given. The cooperation obtained from the subjects was excellent. All those who failed to cooperate were dropped from the experiment, leaving 45 in the commercial gum group and 55 in the K gum group at the end of the experiment.

Some difficulty was experienced in securing a chewing gum which would release the quinone. It was found that the substance was so soluble in the gum base that it was not released into the saliva. However, when the compound was placed in the sugar coating of the gum pellets, it was rapidly and effectively released. The water soluble sodium bisulphite addition compound of the 2-methyl-1,4-naphthoquinone was found to be released readily from both the sugar coated pellets and the slab gum. For this experiment, the sugar coated pellets were used, with the water soluble vitamin compound incorporated in the sugar coating.

Shortly after the start of the experiment, shortages in the supply of gum base required that the formula of the gum be changed. This was done by the addition of calcium carbonate, which lent desirable characteristics to the available gum base. This was unfortunate in regard to our specific purpose, in that the added ingredient tended to neutralize mouth acids and perhaps decrease the amount of decay that might have been expected in the teeth in the gum control group. However, since the 2 gums were identical with the exception of the added vitamin, any effects of the vitamin should be demonstrable, though perhaps less marked.

Six months after the start of the experiment, new radiographs were made for each subject. Further radiographs were obtained at the end of 12 and 18 months, and at 18 months each subject was again examined clinically. All radiographs were compared with the initial radiographs, and the records of the initial and final clinical examinations were compared. For comparisons on the basis of 1 year, the figures for the clinical examinations at 18 months were multiplied by a factor of 2/3. This probably introduced some error, but not enough to invadiate the comparisons.

To furnish an extra control group, clinical examinations and radiographs were obtained of persons not selected for the experiment in the same classes in the school. This group included those who did not volunteer to participate in the experiment, those who were too caries-resistant to be acceptable for the experiment, and those who did not have quite the required number of observable susceptible proximal tooth surfaces. It was recognized that this group theoretically would not be expected to show as much decay as a group of average individuals in the same age range. Likewise, it may be reasoned that the individuals

selected as experimental subjects might show more than average amounts of decay. These differences were considered favorable, however, as they would render positive results more significant.

The extreme difficulty of making truly accurate dental examinations, either clinically or radiographically, is recognized. Most of the previous work along this line has been done by clinical means only. Some investigations, however, have utilized both clinical and radiographic examinations. In others, only radiographs have been used. All methods are open to criticism (16). No entirely satisfactory method has been developed. The problem is further complicated by the questions of whether observed caries is beginning caries, or a continuation of a decay previously present but unobserved. Recurrences of decay around fillings provide further difficulties. In addition, it has been suggested that the number of tooth surfaces where caries might be expected to occur (excluding those where caries would be unlikely to occur) should be considered in estimating caries susceptibility.

In view of these considerations, the records of the experiment (radiographs and records of mouth examinations) were studied to determine the following: 1. The number of new proximal carious surfaces shown by radiographs. 2. The number of new carious surfaces shown by direct examination. 3. The number of new carious surfaces shown by all means (including those that can be found clinically and those which show only on radiographs). 4. The number of proximal carious lesions which have progressed, as judged from radiographs only. 5. The number of recurrences of decay around fillings, as determined by direct clinical examination only.

For purposes of comparison, the following groups were set up: *Vitamin K gum*—Records of subjects participating in the experiment and chewing gum containing the added vitamin (clinical and radiographic examinations). *Regular gum*—Records of subjects participating in the experiment and chewing gum without the added vitamin (clinical and radiographic examinations). *Extra controls*—Records of students of the same classes in school who were not participating in the experiment. The records are the same as for the above groups and cover a period of eighteen months or more for each person. *Previous N. U. students, controls*—Radiographic records of caries progress among students in the dental school in preceeding years (17). *Coast Guard Cadets*—The caries experience of men at the U. S. Coast Guard Academy, as reported by Armstrong, Dean and Singleton (18). (Clinical and radiographic examinations.) *U. S. Public Health Service*—The caries experience of similar age groups as recorded by Klein (19). (Clinical examinations.)

The results for the first 3 groups above are compiled for a period of 1 year, allowing comparison with tabulation of the incidence of caries by other authors, and for a period of 18 months, to take advantage of the greater changes that would be expected to occur in the longer period. The results for the 18 month period allow direct comparison of the vitamin K gum group with the simultaneous control groups, and indirect comparisons with the results of other authors. Where figures were available for only 12 months or only 18 months, they were altered by factors of 2/3 or 3/2 to give bases for comparison.

## RESULTS

The results of the experiment in terms of new cavities are shown in Table I, where comparison is made with corresponding figures from other groups.

From the above figures, it appears that the synthetic vitamin K markedly retards production of new carious lesions and that regular commercial chewing gum containing calcium carbonate also may have an inhibiting effect. The exact amount contributed by each substance cannot be determined, as there is considerable variation in the incidence of caries in comparable age groups as determined by different investigators.

Radiographic determination of caries, yielding a purely objective permanent record which can be checked at will, is subject to errors imparted by variations in the technique of exposing the films, but it may be assumed that the distribution of errors is random. Radiographic examination, furthermore, gives reliable

TABLE I

*New cavities (average per person)*

| | 1 YEAR | | 18 MONTHS | |
|---|---|---|---|---|
| | Radiographs | Clinic and radiographs | Radiographs | Clinic and radiographs |
| Vit. K gum | 0.13 | 0.42 | 0.17 | 0.64 |
| Reg. gum | 0.24 | 0.80 | 0.22 | 1.10 |
| Extra control | 0.36 | 0.92 | 0.55 | 1.40 |
| Prev. students | 1.20 | | 1.80 | |
| Coast Guard | | 2.20 | | 3.30 |
| Pub. Health | | 1.50 | | 2.25 |

data concerning only proximal caries. However, on the basis of radiographic examinations alone, at the 1 year period the vitamin K decreased the caries activity 46% as compared to the regular gum, 64% as compared to the extra control group where caries activity should be less than average, and 89% as compared to caries activity in the group of previous students. On this basis of comparison, the use of ordinary gum containing calcium carbonate filler decreased caries activity 33 to 80%.

For comparison with the results of clinical and radiographic examinations of the U. S. Coast Guard group, the figures for the results obtained by clinical examination of the vitamin K gum, regular gum and extra control groups at the end of 18 months are reduced by one third. On this basis the use of the vitamin K gum for 12 months reduced caries incidence 48% as compared with the regular gum, 54% as compared with the extra control group, 89% as compared with the U. S. Coast Guard group and 72% as compared to Public Health figures. On the same basis, the use of the regular gum containing calcium carbonate reduced caries incidence 13 to 60%.

At the end of the 18 month period, radiographic determinations showed almost the same result for the regular gum containing calcium carbonate as for the vitamin K gum. Clinical and radiographic findings together, however, show a

marked advantage of the vitamin K gum at the 18 month period. On the basis of radiographs alone at the end of 18 months, the vitamin K gum reduced the caries 64% as compared with the extra control group and 89% as compared with the records of previous students. Clinical and radiographic findings together at the end of 18 months show that the vitamin K gum reduced caries 42% as compared with the regular gum, 54% as compared with the extra control group, 89% as compared with the U. S. Coast Guard group and 72% as compared with U. S. Public Health figures. The last comparison is on the assumption that if 2.2 or 1.5 cavities develop in 12 months, 3.3 or 2.25 cavities will develop in 18 months (multiplying by a factor of 3/2). This assumption may not be valid, but it should be noted that the effect of the K gum is fairly constant in all comparisons, whatever the time interval. The above percentage differences are summarized in Table II.

TABLE II

*Percentage decrease in the number of carious lesions in the vitamin K gum group as compared with each of the other groups indicated*

| | RADIOGRAPHIC ONLY | | | RADIOGRAPHIC AND CLINICAL | | | |
|---|---|---|---|---|---|---|---|
| | Reg. gum | Ext. contr. | Prev. students | Reg. gum | Ext. contr. | Coast Guard | Public Health |
| 12 Months..... | 46 | 64 | 89 | 48 | 54 | 89 | 72 |
| 18 Months..... | 23 | 69 | 90 | 42 | 54 | 81 | 72 |

The number of new cavities that may occur is probably a curvilinear function of the number of non-carious, unfilled tooth surfaces in the mouth. The relationship is not direct because of the greater probability of caries occurring on certain surfaces than on certain others. Thus, it is possible that an individual may be extremely susceptible to caries and yet not develop any new cavities in any particular period of time, because all of the tooth surfaces where decay is likely to occur are already filled or decayed. In the present experiment, the subjects using the vitamin K gum had an average of 97.0 unfilled, undecayed surfaces, those using the regular gum had an average of 97.6 such surfaces, and the extra control group, including a number of persons practically immune to caries, and some extremely susceptible, had an average of 98.0 such surfaces.

The distribution of these surfaces available for decay in the 2 groups using gum was excellent, as it was one of the bases on which the subjects were selected, each subject having at least a minimum of unfilled surfaces in positions where decay was likely to occur. The distribution of such surfaces in the extra control groups was poor, however. A result of the difference in distribution would normally have been a much greater incidence of decay in the selected groups (vitamin K gum and regular gum) than in the unselected, extra control group.

Calculations of the number of available surfaces attacked by new carious lesions show that 0.54% became carious in the vitamin K gum group, 0.90% in the regular gum group, and 1.50% in the extra control group. It is unfor-

tunate that these results cannot be compared with determinations by other authors or with figures for our own previous students, since the extra control group apparently experienced much less decay than an average comparable group. However, in spite of the unfavorable weighting of the results, it appears that the vitamin K gum reduced caries activity 40% as compared with the regular gum and 66% as compared with the extra control group.

A similar comparison may be made on the basis of unfilled proximal surfaces only, as determined from radiographic examinations. The advantage is that the radiographic records constitute a permanent, completely objective record in which errors of technique will probably be distributed at random. In such a comparison, little difference appears between the 2 groups using the gum, each showing an increase of 1.0% in the number of carious surfaces. On the same basis, the extra control group showed an increase of 2.8% in the number of carious surfaces. This is a difference of 66% in caries activity. Again it is unfortunate that no comparison can be made on this basis with a truly normal average control group, but it may be pointed out that the reduction of caries by the use of the gum would probably be greater in a comparison with an average group.

Most of the individuals used in the experiment had one or more proximal cavities, the filling of which was not an immediate necessity and the progress of which could be followed with fair accuracy by means of radiographs. These were left unfilled in order to study the progress of decay already started. Observations of these decays indicated that in the group using the vitamin K gum, 30% of the cavities had progressed observably in 18 months, while 70% showed no change. The figures were the same for the group using the regular gum. In the extra control group, 40% of such caries progressed, while 60% did not. It is doubted that these differences are significant, although the individuals in the 2 groups using the gum would normally have been expected to show greater progress of decay than the individuals in the extra control group.

The failure of enzyme inhibitors to arrest caries already well started was not unexpected. It was our observation that decay was not arrested in deep cavities which the subject should have had filled but did not. Shallow cavities, just perceptible on the radiographs, were often arrested so far as could be determined. If the enzyme inhibitors have no appreciable effect on caries well started, this may explain the differences observed among the U. S. Coast Guard Cadets, where a single application of fluorides produced a 15% decrease in the number of new cavities according to interproximal radiographs but no decrease according to clinical examination. Possibly the new cavities later found clinically were actually present the previous year.

It is doubtful if figures on recurrences of decay around fillings can have any significance in this study, since recurrences should vary with the type and quality of the fillings more than with any other single factor. In the present experiment, a further difficulty arose from the fact that the recurrences of decay appeared in very few individuals and were in no sense distributed throughout the groups. The results showed no appreciable differences between the three groups in the amount of recurrent decay.

If the vitamin K being tested reduces the amount of new decay it would be expected that more people in the group using the vitamin K gum would be free of new decay, and conversely, that more people in the control group would show a greater number of new cavities. Such was found to be the case. No individual gave results which were out of line, and the values for every individual in the experiment are included in the figures and graph showing the distribution of caries among the three experimental groups. *Fig. 1* shows this distribution.

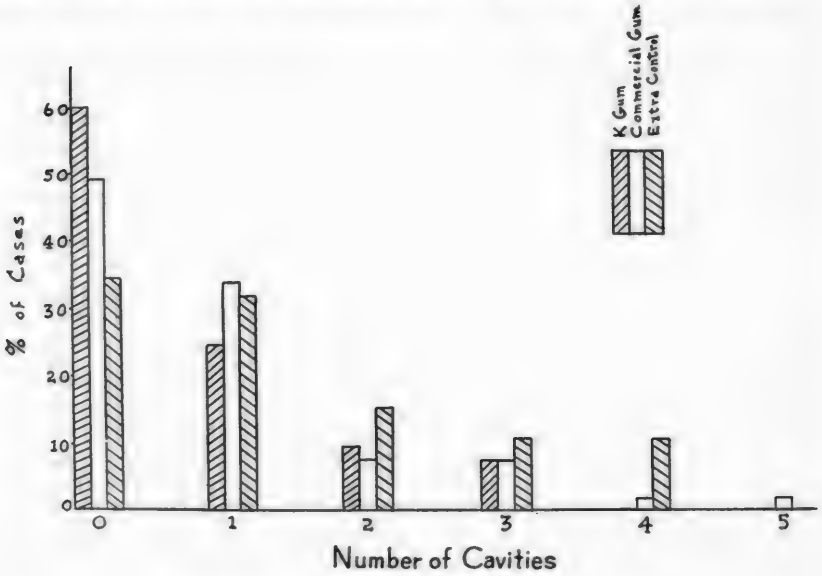


FIG. 1

THE CHEMICAL AND BACTERIOLOGICAL CARIES TESTS

At regular intervals before and during the course of the experiment chemical and bacteriological caries tests were made for each subject in the vitamin K gum and the regular gum groups. The use of the vitamin K gum produced, in most cases, a rapid drop in the *Lactobacillus acidophilus* count, and a concurrent though less pronounced drop in the enamel-dissolving power of the saliva. This response occurred, usually, within a week after the gum was first used. After the initial drop there was a gradual and inconstant rise in both bacterial count and the dissolving action. As time went on, the figures for the tests approached but seldom either reached or exceeded the values in the pre-gum tests.

Why synthetic vitamin K has no persistent effect on the *Lactobacillus acidophilus* counts, yet is effective in controlling caries, is a major question, possibly academic. Preliminary investigations indicate that this phenomenon is related to the action of ammonia in inhibiting *L. acidophilus* (20) which may be an important factor in the control of caries.

## DISCUSSION

From the greatly reduced incidence of new carious lesions among the subjects using the vitamin K gum it appears that the dispersion of the synthetic vitamin K throughout the mouth during the time when acids are likely to form will aid materially in the prevention of decay, even in the presence of considerable sugar. While the neutralizing effect of the calcium carbonate filler was considerable, the difference between the vitamin K group and the regular gum group shows that the enzyme inhibitor was much superior.

Chewing gum appears to be a good vehicle for the inhibitor because of the ease of administration, the proper dispersal of the vitamin in the mouth through the action of mastication, the cleansing effect of the gum, the stimulation of alkaline saliva, and the great popularity of chewing gum with the American public. The material could be placed in mouth washes, dentifrices, and possibly in sugar and syrup. The most important thing at the present time, however, is the further light shed upon the mechanism of dental caries, and the substantiation of the previously stated theory concerning the mechanisms of the initiation and progress of dental caries. According to this theory, an enzyme inhibitor, if present during the periods in which acids would normally form, should inhibit the formation of acids and hence inhibit the initiation of decay. It is pointed out that in the present case the specific effect of the inhibitor was studied, without added complications such as changes in the solubility of the enamel produced by the use of fluorides.

It is of interest to note that the decrease of caries activity produced by the vitamin K is far greater than that observed after the prolonged use of fluorine in drinking water by persons previously susceptible to decay. It is possible that if the concentration of fluorine in drinking water could be increased without harmful effects, a greater inhibition of caries would be observed. However, such increase appears to be impossible and it is to be hoped that some other stable compound will be found which can be used in adequate concentration in drinking water.

Except through an agent placed in drinking water or in some other universally used substances, such perhaps as sugar, the possibility of controlling caries in very large groups is remote. Any method of control which will be successful only if the individual systematically follows instructions, can work only in small groups. This is the difficulty with caries control methods such as elimination of fermentable sugars from the diet, oral hygiene, and medicated chewing gum, though the last offers more promise because of the great popular taste for gum. Until public health studies such as those now under way on the use of fluorine provide a method of caries control which does not depend upon the individual, it will continue to be necessary to use all available methods of caries control wherever possible.

The fact that the synthetic vitamin K may have little or no effect in retarding the progress of decay in lesions already well started does not detract from the theoretical value of the findings. An enzyme inhibitor does not prevent acid formation, but only decreases its rate. The rate of acid formation may be

slowed to such an extent that the saliva can neutralize the acids as fast as they are formed on an undecayed surface of a tooth, or can wash out the substrate before appreciable amounts of acid are formed, while in a pre-existing cavity, because of the mechanical protection afforded, the inhibition may not be sufficient to permit such neutralization and dissipation, so the caries process continues.

## SUMMARY AND CONCLUSIONS

The occurrence of new decay and the progress of old decay was studied radiographically and clinically over a period of 18 months in 2 groups of volunteer subjects and 1 group of persons not actively participating in the experiment. Commercial chewing gum, each piece containing 0.75 mg. of 2-methyl-1,4-naphthoquinone-sodium bisulphite addition compound (synthetic vitamin K), plus calcium carbonate filler, was chewed for at least 10 minutes after each ingestion of food over a period of 18 months by 58 individuals.

The same commercial gum, containing the calcium carbonate filler but not the synthetic vitamin K, was used in the same manner and for the same time by a like group of 45 subjects. No gum was provided for the group of persons not participating in the experiment. No restriction of diet was prescribed.

The vitamin K gum reduced the occurrence of new cavities 60 to 90%, depending on the basis of comparison.

The gum containing calcium carbonate without vitamin K reduced the occurrence of new cavities approximately half as much as the vitamin K gum.

The vitamin K gum probably did not inhibit the progress of caries already present.

No effects contra-indicating the use of synthetic vitamin K were observed.

The 2-methyl-1,4-naphthoquinone for this experiment was supplied kindly by the Abbott Laboratories.

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# THE EFFECT OF PROLONGED INGESTION OF SYNTHETIC VITAMIN K IN RATS[1]

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When it became known that certain of the naphthoquinones possessed antihemorrhagic, or vitamin K, activity, the acute toxicity of these was established (1); but inasmuch as there was little likelihood that these compounds might be ingested over extended periods of time, chronic toxicity tests were not made. Monitor and Robinson (2) fed rats as high as 500 mg. of 2-methyl-1,4-naphthoquinone per kg. per day for a period of 30 days. They found that 500 mg. per kg. was lethal to rats. While 350 mg. produced no significant effect on growth rate it did cause a fall in erythrocyte count and hemoglobin concentrations.

Experiments carried out by other investigators (3) indicated that 2-methyl-1,4-naphthoquinone in doses of 15 to 30 mg. per kg., given intramuscularly, caused vomiting, albuminuria and porphyrinuria in the dog. The porphyrinuria was explained as being due to the oxidation of hemoglobin to methemoglobin by the quinone. This explanation was supported by the observation that the methemoglobin formation as a rule parallels the excretion of porphyrin. The pathological excretion in the dog ceased entirely within a few days. No such symptoms were produced in the rabbit by administration of 30 mg. per kg. of the compound. In man these symptoms were either entirely lacking or were of slight and transient nature following intramuscular injection of 180 to 200 mg. of the substance. K. Fromberg (4) studied the intravenous toxicity of 2-methyl-1,4-naphthoquinone and derivatives in rabbits and dogs. The lethal intravenous dose (rabbit) was 15 to 20 mg. per kg. For rabbits and dogs the 50% lethal dose of the disuccinate (Synkarite) was 100 mg. per kg. Fromberg confirmed the formation of methemoglobin. Andrus and Lord (5) have reported that no toxic effects were produced by doses of as much as 4 mg. of 2-methyl-1,4-naphthoquinone given intramuscularly to man, while Macfie, Bacharach and Chance (6) found that intramuscular injections of 5 to 10 mg. of the substance in man were without harmful effects.

In 1942 it was proposed (7) that 2-methyl-1,4-naphthoquinone might be used in the control of dental caries. This would involve the daily ingestion of small quantities over long periods of time. Since no experiments have been reported in which orally administered doses were ingested daily for extended lengths of time, the following experiments were done. The experiments were

[1] The expense of this work was partly defrayed by a grant from the Good Teeth Council for Children and partly by grants from the Carnegie Corporation of New York and from the Eastman Dental Dispensary. Received for publication October 18, 1945.

conducted simultaneously at 2 institutions. In one institution, comparatively low levels, from 0.005 to 0.125% of the diet, were fed for 3 generations. In the other, rats were fed from 0.1 to 0.8% of the diet for a period of 200 days. The teeth of the test animals were examined at the termination of the experiment in both cases.

## PART I

### DIETARY LEVELS WHICH HAVE NO TOXIC EFFECT[2]

The animals used throughout this investigation were albino rats. The original animals were divided into 4 groups of 10 rats each. The first groups served as controls and received approximately 20 grams per day of a balanced commercial mouse diet. The other 3 groups received the same amount of this feed, to which had been added varying amounts of the test material. The low diet contained 0.005% of the quinone; the intermediate diet, 0.05%; and the high diet, 0.125%. On the basis of the amount of the feed consumed, the rats of the various diet groups ingested approximately 1 mg., 10 mg. and 25 mg., respectively, per rat per day. This corresponds to daily doses of approximately 4 mg. per kg. body weight, 40 mg. per kg. and 100 mg. per kg., respectively, for a 250 gram rat. Each rat was weighed separately at weekly intervals.

After the original animals had been on the experimental diet for several weeks, the females from each group were bred, and they delivered normal litters. All litters were reduced to 5 at birth, and were weaned at the age of 3 weeks. Ten rats of this second generation were kept from each of the 4 groups. Each rat was continued on the same diet that both parents had been receiving. After this second generation had been on the test diet until they had attained full growth, they were bred and a third generation was obtained. Again, these animals were kept in the same diet group as their parents.

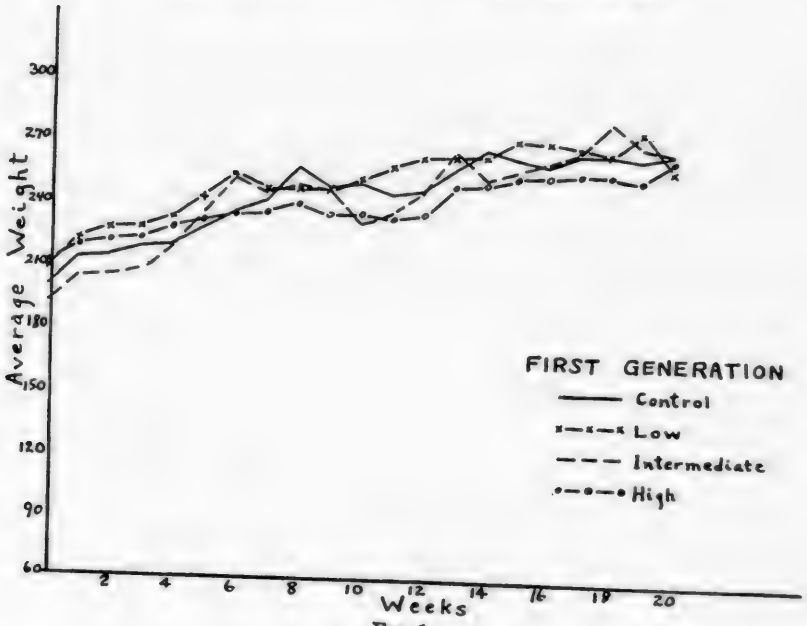
#### *Results on 2-Methyl-1,4-Naphthoquinone*

The weight curves were plotted for each diet group separately; the animals were then subdivided into sex units for further analysis, but since nothing was gained by this, all the essential facts are shown in *figs. 1*, *2* and *3*.

The original animals were started on the experiment after they were nearly fully developed, so that the weight curve has very little to do with growth. The irregularity of the curves is due to the fact that the rats were being bred at intervals throughout the experimental weighing period. There is no significant variation in the pattern of the curves for the 4 groups.

The weight curves for the 4 groups of the second generation follow an almost identical pattern. All 4 groups arrive at the same level at the end of the 20 week period, although the control group attained the maximum weight level a little sooner than the 3 experimental groups. Once more the differences are not great enough to be of any significance.

[2] From the laboratories of Chemistry and Pathology, Northwestern University Dental School.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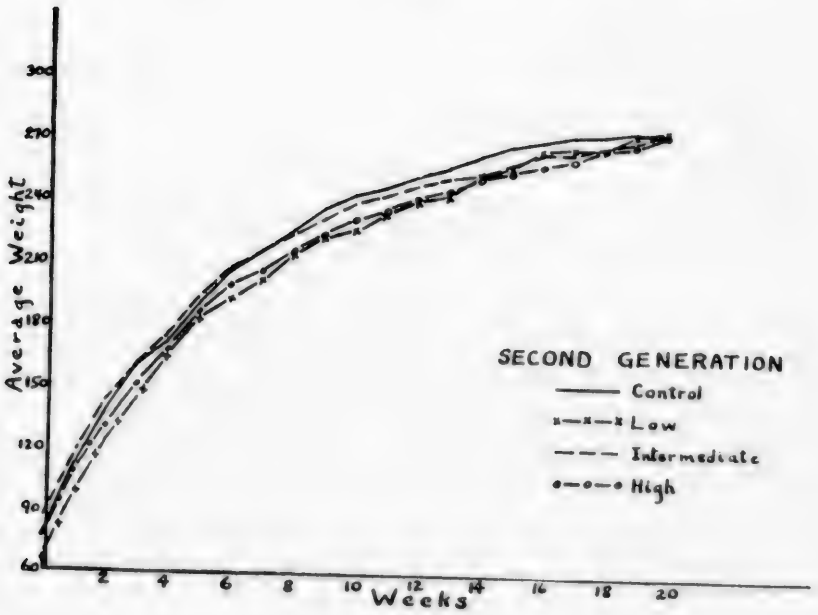
Weeks
FIRST GENERATION
Control
Low
Intermediate
High

FIG. 1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Weeks
SECOND GENERATION
Control
Low
Intermediate
High

FIG. 2

The third generation weights and growth curves are much like those of the second generation, except that growth was somewhat more rapid in the groups consuming the smallest and intermediate amounts of 2-methyl-1,4-naphthoquinone. The slight difference between the control and the high level groups is insignificant, just as is the difference between these 2 and the other 2 groups.

All animals which died during the experimental periods were carefully dissected to determine the cause of the death and other pathological changes, whether related to the cause of death or not. The remaining rats were sacrificed after they had been on the diet for 25 to 57 weeks, and they too were autopsied. All jaws were preserved for examination for caries.

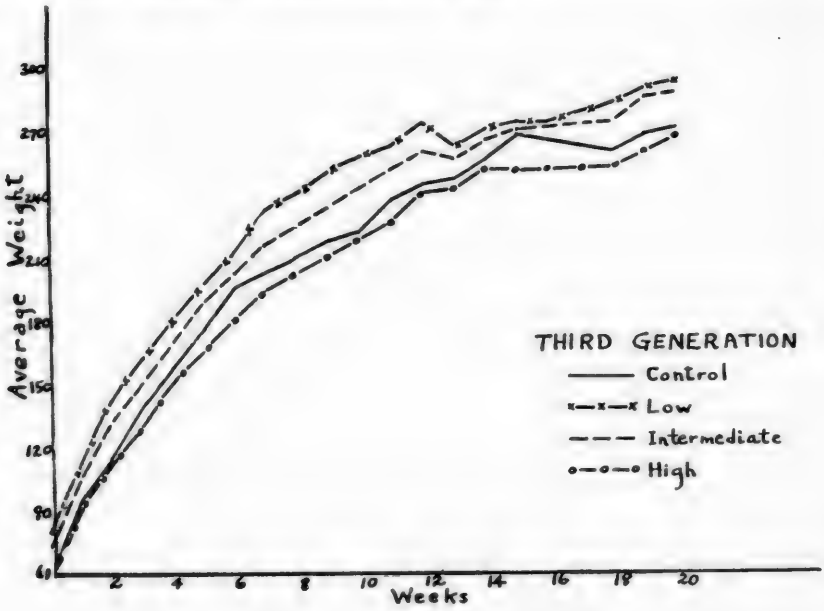



FIG. 3

Most of the animals of the first and second generations had intestinal flat worms, and 4 deaths were caused by impactions of worms in the bowels. These deaths were confined to animals on high and intermediate levels of 2-methyl-1,4-naphthoquinone consumption.

Most of the pathologic changes disclosed were located in the lungs and ranged from coal dust pigmentation, which was quite common and of no material significance, to adhesions about the lungs and lung fibrosis. One animal in the intermediate group, second generation, had small multiple abscesses of the lungs and it had been noted that it was losing weight before it was sacrificed. One control rat of the third generation also had multiple lung abscesses. These changes were related to, or the outcome of, lung infections from which the animals had recovered or from which they had not succumbed at the time they were

killed. It should be noted that most of the recorded natural deaths were due to pneumonia and that this disease was predominant in the rats of the first generation.

Slight enlargements of mesenteric lymph nodes were noted occasionally, twice with tiny cysts; 1 female had fibrous adhesions about the abdominal opening of the Fallopian tubes, and clinically it had been noted that she was sterile

TABLE I

*Pathology report on rats receiving 2-methyl-1,4-naphthoquinone first generation*

| | CONTROL | LOW | INTERMEDIATE | HIGH |
|---|---|---|---|---|
| Number of animals | 10 | 10 | 10 | 10 |
| Natural deaths | 2 | 6 | 5 | 5 |
| Coal dust | 3 | 3 | 3 | 3 |
| Lung pathosis | 1* | 1* | 2* | 2* |
| Intestinal worms | 7 | 3 | 3 | 3 |
| Pigmentation of coat | 1 | 3 | 4 | 3 |
| Other pathosis | 1 (tumor on kidney) | 0 | 1 (lymph node cysts) | 1 (omental cyst) |

*Pneumonia scars.

TABLE II

*Pathology report on rats receiving 2-methyl-1,4-naphthoquinone second generation*

| | CONTROL | LOW | INTERMEDIATE | HIGH |
|---|---|---|---|---|
| Number of animals | 10 | 10 | 10 | 10 |
| Natural deaths | 1 | 1 | 1 | 0 |
| Coal dust | 0 | 2 | 6 | 5 |
| Lung pathosis | 0 | 1* | 2† | 1‡ |
| Intestinal worms | 7 | 7 | 7 | 9 |
| Pigmentation of coat | 0 | 0 | 3 | 8 |
| Other pathosis | 1 (Fallopian tube adhesions) | 0 | 0 | 0 |

* Pneumonia scars.

† One multiple abscesses; one pneumonia scar.

‡ Adhesions and abscesses.

in spite of repeated attempts to mate her with a potent male. This rat was on the control diet.

Many of the older animals, especially the males, had coats that were yellow to rust color about the shoulders and neck, as well as along the middle of the back. While this pigmentation was not wholly confined to the animals which were fed 2-methyl-1,4-naphthoquinone, it was most pronounced in these groups.

The autopsy findings on the animals of the 3 generations are summarized in Tables I, II and III.

Although the weights of the first generation rats were plotted for only 20 weeks, they were kept on the experimental diet for 57 weeks before they were

sacrificed. The second generation animals were killed after 38 to 50 weeks on the diet, while the third generation rats were killed after only 25 weeks on the test. The differences in length of the experimental periods for the three generations accounts for the higher natural death rate among the members of the first generation.

*Results on 2-Methyl-1,4-Naphthoquinone Sodium Bisulfite Addition Product*

Inasmuch as the bisulfite addition product is water soluble and may offer certain advantages over the free quinone, the above procedure was repeated using the sodium bisulfite addition product in place of the free quinone. Although the active ingredient is the quinone, it was thought that there was a possibility that there might be some effect due to more rapid absorption of the water soluble compound. The growth rate curves are in *figs. 4, 5* and *6*.

TABLE III

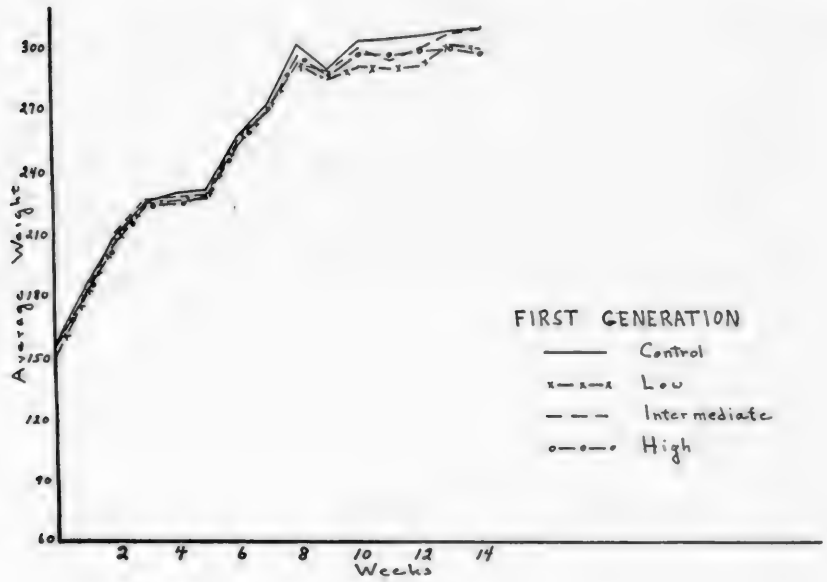
*Pathology report on rats receiving 2-methyl-1,4-naphthoquinone third generation*

| | CONTROL | LOW | INTERMEDIATE | HIGH |
|---|---|---|---|---|
| Number of animals | 10 | 10 | 10 | 10 |
| Natural deaths | 0 | 0 | 0 | 0 |
| Coal dust | 1 | 0 | 3 | 3 |
| Lung pathosis | 1* | 1† | 1‡ | 0 |
| Intestinal worms | 1 | 2 | 4 | 1 |
| Pigmentation of coat | 9 | 6 | 8 | 7 |
| Other pathosis | 0 | 1§ | 0 | 0 |

* Multiple abscesses.
† Pneumonia scars.
‡ Congenital fusion of lobes.
§ Minute solitary retention cyst on kidney.

The growth curves for all 3 generations on the 4 diets were practically identical. In the first generation, the initial weights of all the rats were approximately the same and the growth steadily increased until after they were on the test for 3 weeks. At this period, a rather intensive heat wave was experienced, so that for the next 2 weeks there was very little growth. After this, the usual growth rate was resumed. No differences between groups on the 4 different diets were observed. The second generation growth curves were practically identical. No interruptions in the growth curves were observed. The third generation showed similar growth curves, although the initial weights in 2 of the groups were slightly different than the other 2. Thus the rats on the low diet and the intermediate diet did not quite correspond to the actual weights of those rats on the high and control diets. The rate of growth, however, was very similar. In view of this, it can be said that the ingestion of 2-methyl-1,4-naphthoquinone sodium bisulfite addition product, in the amounts used, has no effect on the growth rate curves of the rats.

The first generation of rats was permitted to live for 61 weeks on the test diet. The second generation was permitted to live for 52 weeks and the third genera-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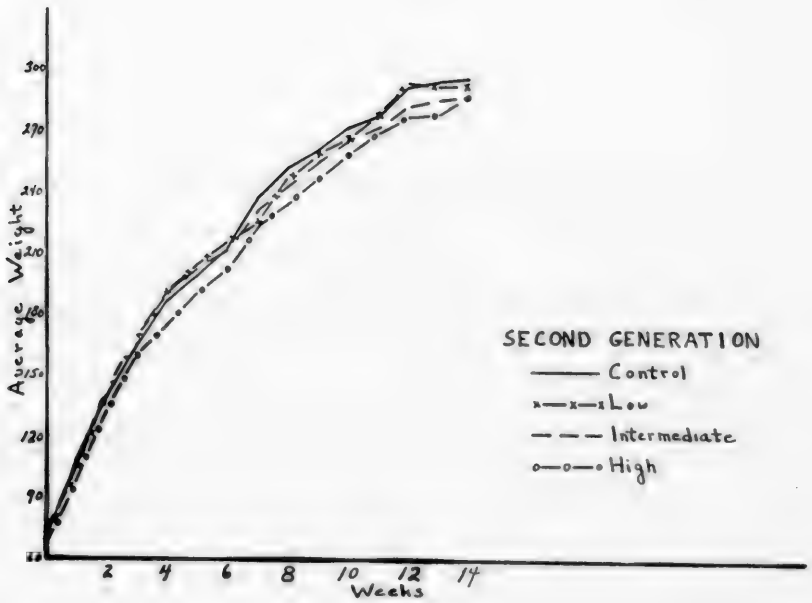
Weeks
FIRST GENERATION
Control
Low
Intermediate
High

FIG. 4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Weeks
SECOND GENERATION
Control
Low
Intermediate
High

FIG. 5

tion permitted to live for a period of 14 weeks. Thus the average age of the rats at death was 64, 45 and 18 weeks respectively. At this time, all the rats were sacrificed and autopsies performed on each of them. The jaws were preserved for examination for caries. Tables IV, V and VI indicate the results of these autopsies.

The first generation suffered 7 deaths during the experiment, all of which were from natural causes. Inasmuch as 3 of the 7 rats that died were in the control groups, the incidence of pneumonia, from which all of the rats died, was no higher in the test groups than in the control group. A few abscesses and other pathosis that were observed showed no relationship to the diet, with the exception

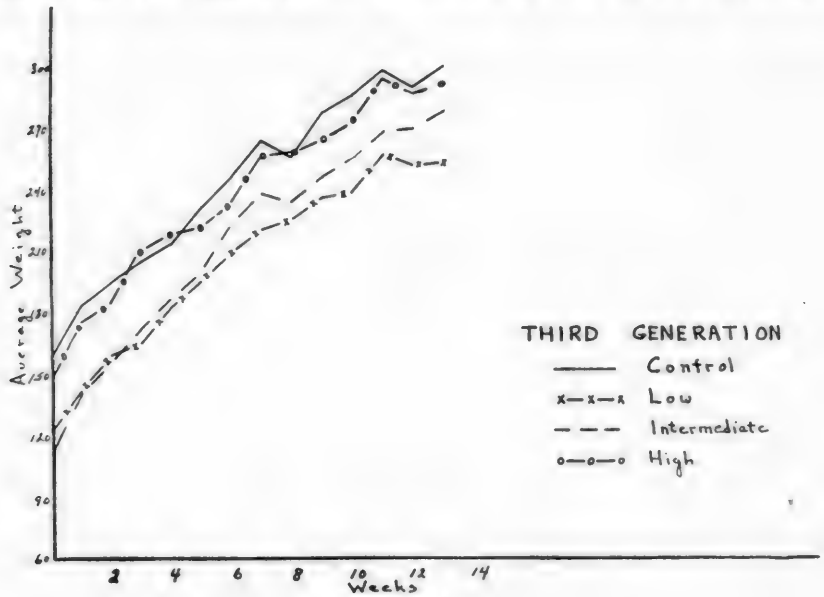


FIG. 6

of the pigmentation of the hair. The fur of all of the rats on the high diet was highly pigmented and the degree of pigmentation decreased in the intermediate and low groups.

The second generation suffered 1 death during the 42 weeks on the diet. This death resulted from pneumonia. The rat was in the intermediate group. The only pathosis that could be attributed to the quinone was the marked pigmentation of the fur of those rats in the high group. The pigmentation was progressively less in the intermediate and low groups. The third generation suffered no deaths from any causes during the 14 weeks in which they were fed the various diets. There was no pathosis, with the exception of pigmentation. The rats on the high quinone diet were a golden yellow color and the pigmentation was progressively less, so that at the end of the experiment the low quinone diet group was approximately the same color as the control group.

Dr. William G. Skillen examined the teeth of the rats of all 3 generations of both experiments. He reported that the teeth of the first 2 generations were so

TABLE IV

*Pathology report on rats receiving 2-Methyl-1,4-naphthoquinone sodium bisulfite addition product first generation*

| | CONTROL | HIGH | INTERMEDIATE | LOW |
|---|---|---|---|---|
| Number of animals | 10 | 10 | 10 | 10 |
| Natural deaths | 3 | 2 | 1 | 1 |
| Lung pathosis | 0 | 1 (abscess) | 1 (abscess) | 2 (1 abscess, 1 tumor) |
| Intestinal worms | 0 | 2 | 2 | 2 |
| Pigmentation | 5 (slight) | 10 (marked) | 10 (moderate) | 6 (slight to moderate) |
| Other pathosis | 0 | 0 | 0 | 1 (ovarian abscess) |

TABLE V

*Pathology report on rats receiving 2-methyl-1,4-naphthoquinone sodium bisulfite addition product second generation*

| | CONTROL | HIGH | INTERMEDIATE | LOW |
|---|---|---|---|---|
| Number of animals | 10 | 10 | 10 | 10 |
| Natural deaths | 0 | 0 | 1 | 1 |
| Lung pathosis | 2 (abscesses) | 2 (abscesses) | 2 | 1 |
| Intestinal worms | 0 | 0 | 1 | 0 |
| Pigmentation | 3 (slight) | 10 (marked) | 10 (slight to moderate) | 1 (slight) |
| Other pathosis | 0 | 1 (inguinal abscess) | 1 (uterine abscess) | 0 |

TABLE VI

*Pathology report on rats receiving 2-methyl-1,4-naphthoquinone sodium bisulfite addition product third generation*

| | CONTROL | HIGH | INTERMEDIATE | LOW |
|---|---|---|---|---|
| Number of animals | 10 | 10 | 10 | 10 |
| Natural deaths | 0 | 0 | 0 | 0 |
| Lung pathosis | 0 | 0 | 0 | 0 |
| Intestinal worms | 0 | 0 | 0 | 0 |
| Pigmentation | 8 (very slight) | 10 (marked | 10 (slight) | 5 (very slight) |
| Other pathosis | 0 | 0 | 0 | 0 |

badly eroded and broken down that no accurate examination could be made. No significant differences were observed in the condition of the teeth from the third generation.

SUMMARY

(1) Albino rats were kept on diets containing 2-methyl-1,4-naphthoquinone or the sodium bisulphite addition product for a period of 3 generations. The diet contained from 0.005% to 0.125% of the free quinone in both cases. A total of 240 rats was used in the experiment.

(2) None of the diets produced any appreciable change in growth rates.

(3) None of the diets produced any pathological changes.

(4) No differences could be observed in the incidence of caries between the test and control animals.

## PART II

### DIETARY LEVELS WHICH PRODUCE TOXIC EFFECTS[3]

A colony of rats (males and females) were placed at weaning on the Hoppert-Webber-Canniff diet which contains 60% coarse corn meal. Rats (males and females) were given an otherwise unsupplemented diet and served as the control group. Three other groups (males and females,[4] each) were given the HWC diets plus 0.1, 0.3 and 0.8% of menadione, respectively. At the start of the experiment, the group receiving the diet of highest menadione content was given a 1.0% menadione diet. This amount produced a diarrhea so severe that the content of menadione was reduced to 0.8% after a few days. The rations were adjusted so that the rats received approximately 10, 30 and 80–100 mg. of vitamin K per rat daily. The inclusion of menadione reduced the growth rate increasingly with higher dietary percentages.

The rats grew fairly well on the 2 lower levels of menadione (*fig.* 7). The male rats on the highest level weighed on the average about 18% less than the control rats after 6 months on the diet. This indicates a moderate order of toxicity, since the intake would correspond to about 500 g. per week in a 70 kg. individual. The rats, especially the males, developed a golden color which was more intense in the rats receiving more menadione. The distribution of the dye lead to the opinion that urinary excretion of the intensely yellow menadione was responsible for the pigmentation of the fur. Perhaps due to the irritating properties of menadione, the male rats appeared to be voiding small amounts nearly all the time; the fur around the genitalia was customarily wet with urine.

After about 200 days on the diets, the rats were sacrificed by severing the abdominal aortae under ether anesthesia. Blood samples were taken from the aortae and red blood cell counts and hematocrit values were determined as shown in Table VII. Although the red blood cell counts for the male rats on the highest dietary level seem low (average, $5.73 \times 10^6$), the average red blood cell counts and hematocrit values of the experimental rats probably do not differ significantly from those of the control rats.

At the time of sacrifice, certain organs were dissected out and weighed (Table

[3] From the laboratories of Biochemistry and Pharmacology, University of Rochester School of Medicine and Dentistry.

[4] There were no female rats fed the highest level of menadione.

VIII). Grossly, only 1 effect of the menadione was evident: the spleens of the male rats receiving the highest level of menadione were very large and black. The average weight of these spleens was more than twice that of the control rats.

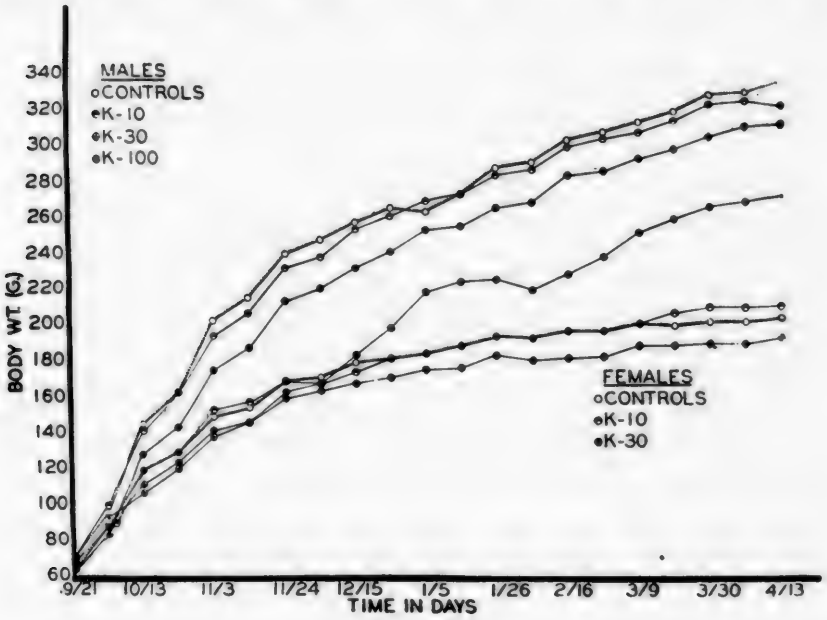


FIG. 7

TABLE VII

*Blood studies of rats receiving menadione*

| DIETARY LEVEL OF MENADIONE (%) | AVERAGE RED BLOOD CELL COUNTS ($\times 10^6$) | AVERAGE HEMATOCRIT VALUES |
|---|---|---|
| Male controls | 8.07 | 46.8 |
| 0.1 | 8.08 | 44.9 |
| 0.3 | 7.00 | 44.1 |
| 0.8 | 5.73 | 44.5 |
| Female controls | 7.79 | 43.2 |
| 0.1 | 6.49 | 44.7 |
| 0.3 | 6.83 | 42.0 |

Samples of the tissues listed in Table VIII and also samples of small and large intestine and sometimes of ovaries or testes were taken for histological examination. Dr. John R. Carter, of the Department of Pathology, reviewed the tissue sections. His conclusion stated that no significant changes from the normal control rat tissues were encountered.

At the time of autopsy, the jaws were dissected sufficiently to permit a careful

inspection of the molar teeth. The technique of this examination by binocular microscope (15×) has been previously described (8). The findings were recorded on charts of the rat molars and have been condensed under 3 headings (Table IX), i.e., (a) average number of carious teeth, (b) average number of teeth totally destroyed and (c) average number of carious cusps. In each case, the values are reported per rat. Since no significant differences were observed in the number of lesions in male vs. female rats or in upper vs. lower jaws, the data for all are grouped as totals. It is clear that in no case did the incorporation

TABLE VIII

*Organ weights of rats receiving menadione*

| DIETARY LEVEL OF MENADIONE (%) | AVERAGE WEIGHTS OF ORGANS | | | | | | |
|---|---|---|---|---|---|---|---|
| | Brain | Liver | Spleen | Kidney | Lungs | Heart | Stomach |
| Part A. male rats | | | | | | | |
| | g. | g. | g. | g. | g. | g. | g. |
| Controls | 1.80 | 9.43 | 0.78 | 1.78 | 1.69 | 1.15 | 1.09 |
| 0.1 | 1.69 | 8.90 | 0.92 | 1.73 | 1.77 | 1.04 | 1.02 |
| 0.3 | 1.55 | 9.09 | 0.79 | 1.72 | 1.93 | 1.00 | 1.11 |
| 0.8 | 1.80 | 9.35 | 1.85 | 1.68 | 1.33 | 0.93 | 1.25 |
| Part B. female rats | | | | | | | |
| Controls | 1.80 | 9.43 | 0.78 | 1.78 | 1.69 | 1.15 | 1.09 |
| 0.1 | 1.69 | 8.90 | 0.92 | 1.73 | 1.77 | 1.04 | 1.02 |
| 0.3 | 1.55 | 9.09 | 0.79 | 1.72 | 1.93 | 1.00 | 1.11 |

TABLE IX

*Experimental caries in rats receiving menadione*

| DIETARY LEVEL OF MENADIONE (%) | NO. OF RATS | AV. NO. OF CARIOUS TEETH | AV. NO. OF TEETH TOTALLY DESTROYED | AV. NO. OF CARIOUS CUSPS |
|---|---|---|---|---|
| Controls | 35 | 4.9 | 0.85 | 12.8 |
| 0.1 | 17 | 4.5 | 0.94 | 11.7 |
| 0.3 | 17 | 5.2 | 0.88 | 13.3 |
| 0.8 | 16 | 5.4 | 1.00 | 14.7 |

of the various amounts of menadione into the HWC diet have any marked effect on the caries incidence. Each of the group averages were compared with the others on the several diets using the Fisher "T" test; in none of the comparisons was a significant difference obtained.

## SUMMARY

(1) Eighty-five male and female albino Wistar strain rats were placed on diets containing 0.1, 0.3 and 0.8% menadione.

(2) Diet containing 0.1% menadione produced little, if any, change in growth rate. Diet containing 0.3% menadione produced measurable diminution in

growth in male and female rats. A well marked growth rate loss occurred in male rats fed a diet containing 0.8% menadione.

(3) The male rats receiving 0.8% menadione in their diets were found to have a low average RBC count; otherwise these counts and average hemocratic values did not differ in any of the experimental groups from the control values.

(4) On autopsy, the spleens of the male rats which received the highest levels of menadione were very large (twice as heavy as those of control rats) and black in color. Otherwise the organs showed normal average weights, and appeared normal grossly and histologically.

(5) Experimental caries developed equally in rats fed various levels of menadione.

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# A TEST OF THE EFFECT OF FLUORIDE-CONTAINING DENTIFRICES ON DENTAL CARIES[1]

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An analysis (1) of available information on the mode of action of fluorine in reducing the activity of dental caries suggested to us that this effect was largely the result of a reaction between the dilute solution of fluorides contained in the drinking water and the external surfaces of the teeth. Strong support for this hypothesis was given by our demonstration (2) that dental caries in school children could be considerably reduced by making as few as 3 applications a year of a more concentrated fluoride solution. This immediately suggested the possibility that more frequent applications of fluorides to the teeth, such as could be brought about by the use of fluoride-containing dentifrices, should produce like effects even if mixtures of a much lower fluoride content were used. This paper reports the results of a 2 year clinical study of the subject.

In September 1942, 4 groups of test subjects were organized from amongst the residents of 2 Catholic Orphanages and the students of Tufts College Dental School. These patients were examined by a dentist using a mirror and probe and all dental defects, fillings and absent teeth recorded. On the basis of the dental conditions of the patients each group was divided into subgroups. These were set up to contain almost identical numbers of persons showing average, more than average and less than average activity of dental decay. This resulted in each experimental subgroup having approximately the same total number of non-carious tooth surfaces at the beginning of the experiment. These various subgroups of patients were then placed on experimental and control dentifrices. Table I shows the composition of various groups at the beginning of the experimental regimes. The test dentifrices were supplied by the Proctor and Gamble Company, and prepared by adding sodium fluoride to a liquid dentifrice similar to their commercial product and to a specially prepared paste. The concentration in the various dentifrices was as follows: paste 3702, 0.01%; liquid 3724, no fluoride; liquid 3725, 0.01%; paste 4211, 0.1%; liquid 4213, 0.1% at approximately pH 4.0.

To ensure proper use of dentifrices, orphanage patients were instructed to use them daily and arrangements were made to provide supervision of all study groups. At St. Vincent's Orphanage the supervising dental hygienist met groups of children and gave instruction in the procedure of tooth brushing and supplied each child with a tooth brush. Thereafter she visited the orphanage regularly

[1] This work was supported by a grant from the Procter and Gamble Co., Ivorydale, Ohio. Received for publication September 28, 1945.

giving 2 oral prophylaxes to the children each year. To prevent interchange of dentifrices the Sisters at the Orphanage distributed the appropriate dentifrice each night to the members of the "red" or "blue" teams and the teeth were cleaned under supervision. Supervisory arrangements at the Home for Destitute Catholic Children were the same as at the Orphanage. Basic dental care was provided by visiting dentists at both institutions aided by members of the staff of Tufts College Dental School. In a few instances dental service was provided by private dentists.

Dental students were under direct supervision of the staff of the Dental School. They were instructed as to the purpose of the experiment and disinterested students excused from participation. Students, except those in the control group, were instructed to abandon their present dentifrices and use the

TABLE I

*Patient groups at beginning of experiment*

| STUDY GROUP | NO. OF PATIENTS | AGE RANGE | DENTRIFRICE SUBGROUPS | | |
|---|---|---|---|---|---|
| | | | Subgroup | No. in subgroup | Dentifrice used |
| St. Vincent's Orphanage | 103 | 5–16 | "Blue" | 52 | 3724 |
| | | | "Red" | 51 | 3725 |
| Home for Destitute Catholic Children | 120 | 4–16 | "Blue" | 60 | 3724 |
| | | | "Red" | 60 | 3725 |
| Sophomore students | 83 | 18–23 | Control | 28 | various |
| | | | Paste | 27 | 3702 |
| | | | Liquid | 28 | 3725 |
| Freshmen students | 80 | 18–23 | Control | 26 | various |
| | | | Paste | 27 | 3702 |
| | | | Liquid | 27 | 3725 |

experimental dentifrice at least once each day. Individual tubes or boxes of paste and new toothbrushes were distributed to the students at the beginning of the experiment and periodically thereafter. Extra distributions of dentifrices were made prior to vacation periods.

Early in the experiment it became apparent that the turnover of patients in the orphanages was much more rapid than we had been given to expect by those in charge. This was presumably the result of an improved financial situation of the patients' families which made possible the reestablishment of homes and the same economic conditions apparently resulted in a great increase in the rate of adoption from amongst the children at the Home for Destitute Catholic Children. Records were kept of the new addresses of patients withdrawing from the Orphanage and the Home for Destitute Catholic Children and dentifrices were delivered or mailed to the new addresses. The hygienist made home visits wherever possible.

During the early months of 1943 a sample reexamination was made of the teeth of 40 of the children at St. Vincent's Orphanage. This gave some evidence of reduction in the activity of dental decay in those children using the fluoride-containing dentifrice.

TABLE II

*Caries increment during first year of using dentifrices*

| STUDY GROUP | SUBGROUP | NO. COMPLETING YEAR | NO. OF SOUND TOOTH SURFACES AT BEGINNING | NO. OF SOUND SURFACES BECOMING CARIOUS AND FILLED (DF) | DF% |
|---|---|---|---|---|---|
| St. Vincent's Orphanage | Fluoride dentrifrice 3725 | 35 | Total 2785 | 123 | 3.2 |
| | | | Permanent 2412 | 80 | 3.3 |
| | | | Deciduous 1373 | 43 | 3.1 |
| | Control dentifrice 3724 | 36 | Total 4024 | 118 | 2.9 |
| | | | Permanent 2950 | 75 | 2.5 |
| | | | Deciduous 1074 | 43 | 4.0 |
| Home for Destitute Catholic Children | Fluoride dentifrice 3725 | 34 | Total 3331 | 140 | 4.2 |
| | | | Permanent 2104 | 106 | 5.0 |
| | | | Deciduous 1227 | 34 | 2.8 |
| | Control dentifrice 3724 | 22 | Total 2268 | 69 | 3.0 |
| | | | Permanent 1461 | 51 | 3.5 |
| | | | Deciduous 807 | 18 | 2.2 |
| Freshmen students | Fluoride paste 3702 | 24 | Permanent (Total) 2571 | 141 | 5.5 |
| | Fluoride dentifrice 3725 | 19 | Permanent (Total) 2046 | 115 | 5.6 |
| | Control | 20 | Permanent (Total) 2123 | 95 | 4.5 |
| Sophomore students | Fluoride paste 3702 | 24 | Permanent (Total) 2560 | 113 | 4.4 |
| | Fluoride dentifrice 3725 | 27 | Permanent (Total) 2858 | 137 | 4.8 |
| | Control | 19 | Permanent (Total) 2076 | 95 | 4.6 |

Beginning in September, 1943 all the patients participating in the experiments were reexamined. Those patients not in residence at the Orphanage or Home were recalled at the time of reexamination, but responded poorly. A second recall notice offering financial inducement produced little better results. The examiner and hygienist then made home visits to all children in the metropolitan

area. Again the results were disappointing, and it became apparent that home cooperation was so poor that the effort to maintain contact with these patients was abandoned. Information on the caries increment in the various groups is submitted in Table II.

Approximately 2 months after the first reexamination the dentifrices used in the experiments were changed. Paste 4211 was substituted for paste 3702. This new paste differed from the old (3702) only in that the sodium fluoride concentration was increased from .01% to 0.1%. Instead of dentifrice 3725 containing a sodium fluoride concentration of 0.01% an acidulated liquid dentifrice (4213) containing 0.1% sodium fluoride was used. The dental student group had remained relatively constant during the first year, but a few substitutions were made to include new students in place of some who had withdrawn.

TABLE III

*L. Acidophilus counts on users of fluoride dentifrices*

| GROUP | SUBGROUP | NO. OF PATIENTS TESTED | ACIDOPHILUS COUNTS | |
|---|---|---|---|---|
| | | | >10,000 | <10,000 |
| St. Vincent's Orphanage | Fluoride dentifrice (4213) | 39 | 14 | 25 |
| | Control dentifrice 3724 | 42 | 16 | 26 |
| Freshmen Students | Fluoride paste 4211 | 28 | 11 | 17 |
| | Fluoride dentifrice 4213 | 28 | 15 | 13 |
| | Control | 26 | 16 | 10 |
| Sophomore Students | Fluoride paste 4211 | 29 | 17 | 12 |
| | Fluoride dentifrice 4213 | 28 | 14 | 14 |
| | Control | 23 | 15 | 8 |

In the Orphanage groups 36 new pupils were examined to take the place of approximately 30 who had withdrawn during the past year. A similar procedure at the Home for Destitute Catholic Children added 60 new patients to that group.

In April, 1944, after 4 months of use of the new dentifrices, *Lactobacillus acidophilus* counts were run on 243 of the patients using the experimental and control dentifrices to determine whether these counts gave any indication of differences in caries activity. The results of this test, which are shown in Table III, gave no evidence of caries reduction in the experimental groups.

During September, 1944, one group of students (Sophomore) who were about to graduate from dental school was reexamined. The other group of students (Freshman) were reexamined during the month of October. In September the last examination of the St. Vincent's group was completed. In November the last reexamination of the Home was made.

Thus the patients in these various groups used the new dentifrices for periods of from 8–10 months. The results of the second period of dentifrice use are given in Table IV. Table V records the increment of caries in the patients who continued the use of dentifrices over a full 2-year period.

## COMMENT

The results presented in Tables II, III, IV and V give no evidence of a reduction in the activity of dental decay in those patients using fluoride-containing dentifrices. The fact that there was no caries reduction in the adult (dental

TABLE IV

*Caries increment during second year of using dentifrices 1943–44*

| STUDY GROUP | SUBGROUP | NO. COMPLETING YEAR | NO. OF SOUND TOOTH SURFACES AT BEGINNING | | NO. OF SOUND SURFACES BECOMING CARIOUS AND FILLED (DF) | DF% |
|---|---|---|---|---|---|---|
| St. Vincent's Orphanage | Fluoride dentifrice | 26 | Total | 2737 | 41 | 1.5 |
| | | | Permanent | 1673 | 25 | 1.5 |
| | | | Deciduous | 1064 | 16 | 1.5 |
| | Control dentifrice | 30 | Total | 3312 | 37 | 1.1 |
| | | | Permanent | 2470 | 26 | 1.1 |
| | | | Deciduous | 842 | 11 | 1.3 |
| Home for Destitute Catholic Children | Fluoride dentifrice | 46 | Total | 3257 | 50 | 1.5 |
| | | | Permanent | 2533 | 48 | 1.9 |
| | | | Deciduous | 724 | 2 | 0.2 |
| | Control dentifrice | 24 | Total | 2531 | 49 | 1.9 |
| | | | Permanent | 1984 | 39 | 2.0 |
| | | | Deciduous | 547 | 10 | 1.8 |
| Freshmen students | Fluoride paste | 24 | Permanent (Total) | 2330 | 122 | 5.0 |
| | Fluoride dentifrice | 19 | Permanent (Total) | 1931 | 81 | 4.2 |
| | Control | 20 | Permanent (Total) | 2028 | 68 | 3.3 |
| Sophomore students | Fluoride paste | 24 | Permanent (Total) | 2447 | 79 | 3.7 |
| | Fluoride dentifrice | 27 | Permanent (Total) | 2721 | 101 | 3.7 |
| | Control | 19 | Permanent | 1981 | 70 | 3.5 |

student) groups is not surprising and is in keeping with Arnold, Singleton and Dean's (3) findings in Coast Guard cadets and the unpublished results (4) of a fluoride mouthwash experiment in dental students. The result in the children's groups is contrary to our expectations and in view of the well established caries-reducing effect produced when fluoride applications are made on the tooth surfaces of children is difficult to explain. The results are even more surprising

when considered in relation to some of our unpublished findings (4) which have demonstrated that when sodium fluoride—hydrogen peroxide mixtures are used in routine dental prophylaxes, given by dental hygienists, a definite caries reduc-

TABLE V

*Caries increment in patients using dentifrice over two year period 1942–1944*

| STUDY GROUP | SUBGROUP | NO. COMPLETING 2 YEARS | NO. OF SOUND TOOTH SURFACES AT BEGINNING | | NO. OF SOUND SURFACES BECOMING CARIOUS AND FILLED (DF) | DF% |
|---|---|---|---|---|---|---|
| St. Vincent's Orphanage | Fluoride dentifrice | 16 | Total | 1670 | 71 | 4.3 |
| | | | Permanent | 928 | 43 | 5.2 |
| | | | Deciduous | 742 | 28 | 3.7 |
| | Control dentifrice | 19 | Total | 2159 | 71 | 3.3 |
| | | | Permanent | 1553 | 57 | 3.7 |
| | | | Deciduous | 606 | 14 | 2.3 |
| Home for Destitute Catholic Children | Fluoride dentifrice | 18 | Total | 1746 | 110 | 6.3 |
| | | | Permanent | 1287 | 97 | 7.5 |
| | | | Deciduous | 459 | 13 | 2.8 |
| | Control dentifrice | 14 | Total | 1461 | 81 | 5.5 |
| | | | Permanent | 1003 | 62 | 6.2 |
| | | | Deciduous | 458 | 19 | 4.1 |
| Freshman students | Fluoride paste | 24 | Permanent (Total) | 2571 | 263 | 10.2 |
| | Fluoride dentifrice | 19 | Permanent (Total) | 2046 | 196 | 9.6 |
| | Control | 20 | Permanent (Total) | 2123 | 163 | 7.7 |
| Sophomore students | Fluoride paste | 24 | Permanent (Total) | 2560 | 192 | 7.5 |
| | Fluoride dentifrice | 27 | Permanent (Total) | 2858 | 238 | 8.3 |
| | Control | 19 | Permanent (Total) | 2076 | 165 | 7.9 |

tion results. In view of accumulating evidence indicating that the caries-reducing effects of fluorine are most marked in young teeth, it seemed worthwhile to analyze our findings to see if they indicated any increased evidence of caries prevention in the newly erupted molars as compared with the older molars. No evidence of such an effect was found.

It is difficult to suggest reasons why no caries reduction was produced in

our groups of children. The possibility that the mixing of sodium fluoride with other dentifrice constituents rendered it inactive is largely ruled out by preliminary test tube studies which showed that the dentifrice mixtures exerted a solubility reducing effect on powdered enamel. Another possible explanation is that because of the relative inefficiency of tooth brushing, especially in children, in reaching all the surfaces of the teeth the fluoride solutions were not brought as intimately in contact with the tooth surfaces as is done when fluoride applications are made by a dentist on a tooth surface which has been mechanically cleansed. This would be particularly true of the interproximal spaces and tooth fissures where most caries in children originates. The difference in caries incidence in our groups of children between the first and second year of the experiment introduces a disturbing factor and suggests that our results may have been vitiated by some extraneous factors such as modifications of institutional regulations or changes in diet occasioned by war-time conditions. At the present time however it is not possible to account for this marked reduction of caries activity in a satisfactory way.

SUMMARY

A 2-year study of the effect of the use of fluoride-containing dentifrices was carried out on groups of dental students and orphanage children. No evidence of a reduction of caries activity was found.

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# OBSERVATION OF INCREASED CARIES ACTIVITY FOLLOWING INTERRUPTION OF TOPICAL FLUORINE APPLICATIONS[1]

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The hypothesis that the incidence of dental caries may be reduced by applying fluoride solutions to the teeth had its origin in the findings of a large number of investigations into the relationship between fluorine and tooth decay. Dean (1, 2, 3, 4) established the inverse relation between caries and the amount of fluorine in drinking water. Armstrong and Brekhus (5) discovered that unaffected enamel of carious teeth contains a significantly smaller proportion of fluorine than enamel of sound teeth. Volker (6, 7) demonstrated, in vitro, that fluorine is adsorbed from solutions by powdered enamel, and that artificially fluorosed enamel and dentin are more resistant to acid dissolution than normal dental tissues. In vivo experiments by Perry and Armstrong (8) verified the ability of enamel to take up fluoride from solution. Finally, Sognnaes (9) reported a reduction of experimental caries in rats by locally applying a potassium fluoride solution to the teeth.

The postulate was clinically tested in 1942. Bibby (10) studied the effect of a sodium fluoride solution containing 0.1% fluorine applied at 4-month intervals over a period of 1 year to the teeth of diametrically opposed quadrants in 89 children 10 to 13 years of age. Cheyne (11) observed the influence of a solution of potassium fluoride containing 0.05% fluorine applied twice to all the teeth of 27 children, 4½ to 6 years old, during a 3- to 3½-month period. Nineteen age-comparable children served as control. Both investigators described an approximately 50% reduction in the incidence of caries as a result of the applications. Bibby (12) later reported a decrease in effectiveness on the basis of data obtained in the 2nd year of his study. Recently, Knutson and Armstrong (13) found a 40% reduction of caries incidence in treated quadrants as compared with untreated quadrants in 289 children and with 326 entirely untreated controls. Treated children received 7 to 15 applications of a 2% solution of sodium fluoride during an 8-week treatment period. Observations were made 1 year after treatment.

Present data were obtained in an attempt to determine whether the caries-inhibiting influence of topically applied fluorine is maintained following interruption of serial applications. The study was begun in the summer of 1942 and completed as far as reported 2 years later.

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## EXPERIMENTAL

*Subjects.* A group of 21 unselected volunteer children, 13 boys and 8 girls, living in and about Brockport, New York, were the subjects of investigation. All were native born, and for the most part spent their entire lives in the vicinity

TABLE I

*Caries activity in 361 permanent and deciduous teeth of 13 boys and 8 girls 2 to 13 years of age following a year of periodic topical applications of fluorine and a year of suspended treatment*

| SUBJECT | SEX | AGE AT 1ST EXAM | NUMBER OF NaF APPLICATIONS | NUMBER OF TEETH STUDIED | | NUMBER OF LESIONS 1ST EXAM | NEW LESIONS AND EXTENSIONS OF LESIONS | | CHANGE IN CARIES RATE DURING YEAR OF SUSPENDED NaF APPLICATIONS |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Decid | Perm | | During year of treatment | During year of no treatment | |
| 1 | M | 2 | 7 | 20 | — | 0 | 0 | 2 | 2 |
| 2 | M | 2 | 10 | 19 | — | 0 | 0 | 1 | 1 |
| 5 | M | 3 | 7 | 20 | — | 0 | 0 | 3 | 3 |
| 4 | M | 4 | 6 | 18 | — | 5 | 0 | 0 | 0 |
| 5 | F | 4 | 8 | 14 | — | 0 | 0 | 1 | 1 |
| 6 | M | 5 | 11 | 12 | — | 20 | 13 | 14 | 1 |
| 7 | M | 6 | 7 | 12 | — | 8 | 5 | 7 | 2 |
| 8 | F | 6 | 9 | 10 | 4 | 4 | 4 | 9 | 5 |
| 9 | M | 7 | 9 | 10 | 8 | 10 | 10 | 14 | 4 |
| 10 | M | 7 | 4 | 10 | 4 | 17 | 6 | 6 | 0 |
| 11 | F | 8 | 11 | 4 | 4 | 10 | 2 | 4 | 2 |
| 12 | M | 8 | 5 | 5 | 11 | 6 | 0 | 0 | 0 |
| 13 | F | 8 | 5 | 2 | 13 | 9 | 2 | 4 | 2 |
| 14 | M | 9 | 7 | 2 | 12 | 15 | 3 | 4 | 1 |
| 15 | F | 9 | 9 | 2 | 12 | 5 | 1 | 3 | 2 |
| 16 | M | 10 | 4 | 9 | 12 | 24 | 5 | 7 | 2 |
| 17 | F | 10 | 5 | — | 16 | 11 | 1 | 4 | 3 |
| 18 | M | 11 | 10 | — | 22 | 9 | 3 | 6 | 3 |
| 19 | F | 11 | 10 | 1 | 17 | 12 | 1 | 2 | 1 |
| 20 | M | 12 | 3 | — | 28 | 17 | 6 | 5 | −1 |
| 21 | F | 13 | 8 | — | 28 | 21 | 2 | 5 | 3 |
| Treated Teeth | | | | 86 | 96 | 108 | 32 | 51 | 19 |
| "Untreated" Teeth | | | | 84 | 95 | 95 | 32 | 50 | 18 |
| Totals | | | | 170* | 191† | 203 | 64 | 101 | 37 (58% Increase) |

* 77 anterior and 93 posterior teeth.
† 97 anterior and 94 posterior teeth.

of Brockport, an area in which water supplies contain less than 0.1 part per million of fluorine. The sexes were well distributed in ages ranging between 2 and 13 years at the beginning of the study (Table I). The average child was about 8 years old.

*Examinations.* Thorough oculo-instrumental examinations with excellent

equipment and under good lighting conditions were made initially and at the end of the 1st and 2nd years thereafter. The stage of development of the dentition, loss of teeth, location and extent of carious lesions, and presence of fillings were carefully charted. Right and left posterior interproximal (bitewing) radiographs supplemented the visual record of every examination of all but 3 of the youngest subjects.

*Fluorine applications.* The children were assembled at monthly intervals during the 1st year of study to receive topical administrations of an aqueous sodium fluoride solution containing 0.1% fluorine. An application consisted of repeatedly drawing a pledget of absorbent cotton, well moistened with the solution, over the exposed surfaces of the maxillary and mandibular teeth of 1 side. Treated teeth were in this manner kept moist for at least a minute. The jaws were held open during the entire procedure. Subjects were instructed to spit and thoroughly rinse the mouth after each treatment. The number of applications per individual ranged from 3 to 11 (Table I) and averaged 7.4. Care was exercised to restrict the fluoride solution to the teeth to be treated, but it was not found feasible to isolate them with cotton rolls or other such device. No attempt was made to clean or otherwise prepare the teeth for treatment, or influence the oral hygienic habits of the children.

*Data compilation.* Every tooth that was erupted and in position at the time of the initial examination and had not been extracted or exfoliated in the final charting was studied individually. Others were omitted from consideration, thus rendering the study one of teeth rather than of persons. Tabulated information included the number of filled and unfilled carious lesions. Discontinuities in smooth surfaces visualized radiographically were assumed to represent caries. Carious pits or fissures in the same occlusal fossa were regarded as 1 lesion or focus of decay. Gross destruction of the crown was rated according to the number of decay foci indicated by clinical and radiographic evidence. An interproximal filling in a posterior tooth extending no farther than the center of the occlusal surface was considered as representative of 1 lesion, one extending beyond the center as 2, and a mesio-occluso-distal filling as 3. Extensions of occlusal restorations into the buccal or lingual surfaces were counted as evidence of additional lesions. In the 2nd and 3rd examinations, an obvious increase in the amount of tooth structure destroyed by a lesion observed in the previous examination was scored as 1 and added to the previous score for that tooth as evidence of caries activity in the interim. A new addition to a filling was scored likewise.

## RESULTS AND DISCUSSION

The findings are indicated in Table I. Altogether, the investigation involved 361 teeth, 170 deciduous and 191 permanent. Of these, 182 were treated and 179 were originally intended as "untreated" controls.[2] Caries scores in the initial examination were 108 in treated teeth and 95 in "untreated" teeth, a total

[2] Parity in the numbers of new lesions observed in treated and "untreated" teeth would indicate that measures taken to isolate them were ineffective. The data should not be interpreted as signifying a lack of influence on the part of the fluoride solution.

of 203. After a year of fluorine applications, these scores were increased by 32 in each category, raising the total score to 267. Following interruption of fluorine administrations during the 2nd year, the score for treated teeth was increased by 51 and that for "untreated" teeth by 50, resulting in a final aggregate score of 368: 24 in deciduous anterior teeth, 18 in permanent anterior teeth, 170 in deciduous molar teeth, and 156 in permanent posterior teeth.

Increased caries activity in the year following suspension of fluorine applications may be significant. Combined data from treated and "untreated" teeth indicate a growth of 58% in the yearly caries rate. In view of the wide age range represented and the consistency with which the rate increased among the individuals studied, it would appear quite possible that the augmented caries experience was the result of loss of effectiveness of the caries-inhibiting influence of fluorine topically applied during the previous year.

Available evidence does not indicate the complete relationship between the number or frequency of applications and the degree or longevity of caries inhibition. However, it would appear that 2 to 4 topical administrations per year are significantly effective, whether they be supplied at intervals throughout the year (12) or confined to a period of a few weeks (11, 13). A single application is apparently of no avail in adults (14).

## SUMMARY

A 2-year investigation of the incidence of caries in 361 teeth of 21 children between 2 and 13 years of age revealed a marked increase in rate following suspension of periodic topical applications of a sodium fluoride solution received over a period of 1 year. The results suggest that the caries-inhibiting effect of a series of topical fluorine administrations is restricted in the absence of continued applications.

The authors are indebted to Drs. J. F. Volker and H. C. Hodge for their efforts in initiating the study, to Drs. A. H. Pearson and J. E. Gilda for assistance, and to Dr. K. W. Moore for his cooperation in placing at our disposal the facilities and personnel of his office in Brockport, New York.

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# SALIVARY DILUTION OF 1–1000 SODIUM FLUORIDE SOLUTION USED AS A MOUTHWASH[1, 2]

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Since January 1, 1944, the Dental Division of the Metropolitan Life Insurance Company, has offered as a mouthwash a 1–1000 aqueous solution of sodium fluoride to patients who have just completed dental prophylactic cleansing in the company clinic. The object of this procedure has been to conduct an experiment in caries control. It is not proposed to analyze company dental records for caries until more time has elapsed, but in the meanwhile, as a guide in technique, we wished to know how much a mouthwash of the content described would be diluted by saliva during the period it was held in the mouth.

One hundred cases were selected at random, as they appeared for their periodic cleansing in the period from May 16, 1944 to March 22, 1945. Both sexes were included. The ages of the individuals varied from 17 to 59. Twenty-five cc. of a 1–1000 aqueous solution of sodium fluoride, flavored, were measured out by means of a graduate. This solution was held in the mouth for 2 minutes and the resultant material was again measured as to volume. The same procedure was repeated for a 3 minute period. The mouths of the patients were assumed to contain approximately as much fluid after spitting as before the introduction of the wash. To assure accurate measurement when bubbling occurred, 1 drop of caprylic alcohol was introduced. In 50 individuals the 2 minute test was made first, and in the remaining 50 persons the 3 minute test was made first. To allow sufficient time between tests one was made at the beginning of the cleansing and the other toward the end of the cleansing periods. Those individuals showing a lowered volume, were eliminated from this portion of the study.

When 100 cases with both the 2 and 3 minute tests had been observed and the findings recorded, the totals were tabulated so as to find the average volumes for each test period. The average increase in volume in each group was then calculated and from this the average rate of dilution was found.

The dilution of the fluoride solution by the saliva, in two minutes was 0.8 cc., or 0.40 cc. per minute. Expressed as a percentage this is as a 3.2% dilution by the saliva. The dilution in 3 minutes was 1.3 cc. or 0.43 cc. per minute. In percentage this was 5.2% dilution. Thus, if we disregard absorption of fluoride by oral tissues and measure the effect of dilution alone, the solution changed in

[1] The opinions or assertions contained herein are not to be construed as official or reflecting the laws of the Navy Department or the Naval Service at large (Article 113, United States Navy Regulations).

[2] Received for publication September 26, 1945.

[3] Now serving in Dental Corps, USNR.

2 minutes from 1–1000 (0.1%) solution to 1–1032 (0.0969%) solution, and in 3 minutes to a 1–1052 (0.0951%) solution. It is of interest to compare these results with those of Becks and Wainwright[4] who determined the rate of flow of resting saliva for 2 and 3 minute periods in a sample of 661 persons 5 to 95 years of age. These workers observed an average flow of 0.63 cc. in 2-minute periods (as against 0.8 cc. in our cases), and an average flow of 0.95 cc. in 3 minutes period (as against 1.3 cc. in our cases).

The average increase in volume of the 2 and 3 minute groups was analyzed to find whether the process of dental cleansing produced any change in salivary flow. The resultant calculations made upon 2 minute tests, showed 0.67 cc. to be the average increase of volume for tests made at the beginning of cleansing, and 0.90 cc. as the average increase for tests toward end of cleansing. We see no important difference between these 2 figures and may conclude that the process of cleansing did not appreciably affect the volume change. For 3 minute tests, 1.39 cc. and 1.30 cc. average increases of volume were found, and again we conclude that the process of cleansing did not appreciably affect the volume change.

Table I includes data from all 110 cases, including the tests on the 10 individuals showing a below volume result. While it was felt to give a truer picture to eliminate the below volume cases in obtaining the average rate of dilution, it was thought to be of interest to include in this table all 110 cases. Subdivision of the data has been carried out to show the possible influence of the dental cleansing process, the sex and age of the patient, and the season of the year during which the test was performed. It will be noted that no striking differences in grouping appear as a result of the sub-division of the data. The greatest number of individuals with 2-minute retention of the mouthwash showed an increase by dilution of from 0.5 to 0.9 cc. The same concentration of persons is found in each of the subdivisions of the 2 minute test data. Three-minute rinses show most commonly an increase of from 1.0 to 1.4 cc., and again all subdivisions of the 3 minute data show similar most common increases. The patients showing loss of volume constitute only 9% of the total number of cases. Even these cases are so evenly distributed among the various subdivisions that no hint is given as to what condition if any would be most likely to produce loss in volume. A larger number of cases, of course, would be needed here in order to give a reliable answer.

Table II shows averages for only those individuals in which volume increased. Here some significant differences are found by subdivision of the data. In "all individuals" there was an average increase of 0.78 cc. for the first 2 minute retention period and an increase of 1.34 cc. for the 3 minute retention period. The average increase of volume for males is much greater than for females in both the 2 and 3 minute retention periods. Age does not seem to be a significant factor except in the 50–59 year age group where a higher average increase in volume is found than in the other age groups. Season does not seems to be a significant factor, nor does the time of the test as related to dental cleansing.

[4] Becks, H., and Wainright, W. W., *J. D. Res.*, **22**: 391, 1943.

## TABLE I

*Volume changes in cc. after retention of 25 cc. of 1–1000 aqueous solution of sodium fluoride mouthwash, in mouth for 2 and 3 minute periods; 110 home office employees of Metropolitan Life Insurance Company*

| CASE DATA | TOTAL | TWO MINUTE RETENTION | | | | | | | | THREE MINUTE RETENTION | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | −1.5 to −3.4 | 0 to −1.4 | 0 to .4 | .5 to .9 | 1.0 to 1.4 | 1.5 to 1.9 | 2.0 to 2.4 | 2.5 and over | −1.5 to −4.4 | 0 to −1.4 | 0 to .4 | .5 to .9 | 1.0 to 1.4 | 1.5 to 1.9 | 2.0 to 2.4 | 2.5 to 2.9 | 3.0 and over |
| All individuals | 220 | 5 | 5 | 21 | 40 | 17 | 13 | 5 | 4 | 5 | 5 | 7 | 19 | 32 | 16 | 12 | 8 | 6 |
| Before cleansing | 111 | 3 | 2 | 15 | 19 | 11 | 4 | 1 | 2 | 3 | 2 | 2 | 8 | 7 | 8 | 6 | 5 | 3 |
| After cleansing | 109 | 2 | 3 | 6 | 21 | 6 | 9 | 4 | 2 | 2 | 3 | 5 | 11 | 15 | 8 | 6 | 3 | 3 |
| Males | 68 | 2 | 1 | 2 | 13 | 6 | 6 | 2 | 2 | 2 | 1 | 1 | 4 | 9 | 7 | 4 | 5 | 1 |
| Females | 152 | 3 | 4 | 19 | 27 | 11 | 7 | 3 | 2 | 3 | 4 | 6 | 15 | 23 | 9 | 8 | 3 | 5 |
| Age group | | | | | | | | | | | | | | | | | | |
| 17–29 | 90 | 2 | 2 | 13 | 17 | 6 | 3 | 2 | 1 | 1 | 3 | 3 | 9 | 13 | 6 | 5 | — | 4 |
| 30–39 | 64 | 1 | 3 | 3 | 11 | 6 | 6 | — | 1 | 3 | 1 | 1 | 7 | 9 | 4 | 4 | 4 | — |
| 40–49 | 44 | 1 | — | 5 | 9 | 3 | 1 | 3 | — | — | 1 | 3 | 2 | 8 | 4 | 1 | 2 | 1 |
| 50 and over | 22 | 1 | — | — | 3 | 2 | 3 | — | 2 | 1 | — | — | 1 | 2 | 2 | 2 | 2 | 1 |
| Seasons* | | | | | | | | | | | | | | | | | | |
| Winter | 56 | 2 | — | 5 | 9 | 6 | 4 | 1 | 1 | 2 | — | 3 | 5 | 7 | 5 | 3 | 2 | 1 |
| Spring | 54 | 1 | 2 | 7 | 9 | 3 | 2 | — | 3 | 1 | 2 | 2 | 4 | 7 | 4 | 2 | 3 | 2 |
| Summer | 48 | 1 | 1 | 5 | 12 | 2 | 2 | 1 | — | 1 | 1 | — | 6 | 9 | 1 | 5 | 1 | — |
| Fall | 62 | 1 | 2 | 4 | 10 | 6 | 5 | 3 | — | 1 | 2 | 2 | 4 | 9 | 6 | 2 | 2 | 3 |

* As of Dec. 21, Mar. 21, June 21, Sept. 21.

## TABLE II

*Volume increases in cc. after retention of 25 cc. of 1:1000 aqueous solution of sodium fluoride mouth wash in mouth for 2 and 3 minute periods; 100 individuals*

| CASE DATA | AVERAGE* "INCREASE VOLUME" CHANGE (COUNTING INCREASES ONLY) | |
|---|---|---|
| | Two minute retention | Three minute retention |
| All individuals | .78 | 1.34 |
| Before cleansing | .67 | 1.38 |
| After cleansing | .90 | 1.30 |
| Males | 1.02 | 1.52 |
| Females | .67 | 1.26 |
| Age group | | |
| 17–29 | .63 | 1.33 |
| 30–39 | .85 | 1.26 |
| 40–49 | .71 | 1.19 |
| 50–59 | 1.44 | 2.11 |
| Seasons | | |
| Winter | .81 | 1.25 |
| Spring | .81 | 1.52 |
| Summer | .59 | 1.18 |
| Fall | .88 | 1.39 |

* Lower limit used in each case as weights.

However, in the summer period we note a slightly smaller increase than is found at other seasons.

In the course of this study several problems arose. One of these involved instances where the volume did not increase or where it even fell below 25 cc. after the mouthwash was held in the mouth for 2 or 3 minute periods. The factors here may be: 1. Salivary flow may have been inhibited, or reduced below the rate of tissue absorption. 2. The tissues in these cases may have absorbed more than usual, but not more than with water, since control tests with plain water produced similar results. 3. Not all of test solution may have been spit out. 4. Some of the solution may have been swallowed.

Where the volume of recovered wash was less than 25 cc., repeated tests with water were substituted for the sodium fluoride tests in order to obtain the best possible accuracy. The same results were obtained where the water was substituted. Ten cases of consistently decreasing volume were found, or 9% of the total of 110 cases, and all were eliminated from the main body of the study. If swallowing during the test or afterward (where spitting was complete) is assumed in these 10 cases, then this phenomenon must be taken into consideration in prescribing stronger solutions in practice. We might expect, pending more extensive study, that some 9% of all patients would swallow small amounts of any mouthwash, to the amount of perhaps 6% ($\frac{1}{17}$) of the dose administered.

## SUMMARY

Through accurate measurements on 100 individuals selected at random, the rate of dilution of a 1–1000 aqueous solution of sodium fluoride held in the mouth for 2 and 3 minute periods was ascertained. We found that in 2 minutes the solution changed from 1–1000 (0.1%) to a 1–1032 (0.0969%) solution; while in 3 minutes there is a change from 1–1000 (0.1%) to a 1–1052 (0.0951%) solution. A loss of volume occurred in 9% of all cases tested, but these cases were excluded from the foregoing computation.

A subdivision of data into various categories showed that a definitely greater increase in volume occurred among males than among females on the average, and in persons of both sexes in the age group 50 to 59, though all younger age groups showed fairly uniform increases. Season and conducting of the test before or after the process of dental cleansing made little difference in the result.

In the instances where a loss of volume occurred it is estimated that possibly 6% of the dose administered was swallowed. This finding should be taken in consideration in prescribing mouth rinse of greater toxicity than the present one.

We are greatly indebted to Dr. N. R. Blatherwick, and Mr. M. Spiegelman of the Metropolitan Life Insurance Company for their kind assistance in this work.

# THE ISOLATION OF CANDIDA ALBICANS FROM A ROOT CANAL UNDERGOING PENICILLIN THERAPY[1]

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This case is particularly interesting because, under aseptic precautions, a yeast-like microorganism was isolated from the canal in 3 successive cultures and because control of this microorganism by penicillin therapy was unsuccessful.

## CASE HISTORY

The patient, a 31 year old woman, had visited her dentist for treatment of a painful upper right first incisor. The dentist opened into the canal and treated the tooth over a period of several weeks but subacute clinical symptoms persisted. The patient was first seen by one of us (M. B.) on *June 6*. She complained of marked tooth tenderness on pressure and a feeling of fullness in the periapical region. A radiograph revealed an area of rarefaction about the apex of the root. The canal was open and no apparent clogging of the root apex was discernable. Penicillin therapy was instituted. The canal was irrigated with 1000 units and a penicillin saturated point containing about 1000 units was inserted. The canal was not sealed. *June 19*. The canal was again irrigated with penicillin, a saturated penicillin point enclosed and the canal sealed with cement. *June 21*. This treatment was renewed. *June 25*. The root canal contents were cultured. The rubber dam was applied, the crown of the tooth swabbed with tincture of iodine, then alcohol, dried, and the cement seal removed with a sterile bur. The cavity was treated in a similar fashion and the cotton point removed. A sterile point was inserted with sterile forceps, removed from the canal and dropped into a tube of sterile Difco brain heart infusion broth. A growth of a yeast-like microorganisms developed. The penicillin treatment was nevertheless continued. *July 6*. A second culture was taken with similar precautions and again a yeast-like microorganism was obtained in pure culture. Penicillin therapy was continued. *July 9*. Penicillin renewed. *July 12*. The patient complained of apical tenderness and a swelling of the labial gingiva over the root apex was noticeable. A third culture secured under aseptic precautions produced growth only of the yeast-like microorganism. Penicillin therapy was continued. *July 16*. A fistula had developed opening on the labial gingiva. The tooth was left open after irrigation and the installation of a penicillin saturated point. *July 23*. The patient stated the tooth was again comfortable. A fourth culture revealed the absence of the yeast-like microorganism but the presence of a streptococcus. Penicillin was again employed as previously stated. *July 25*. Culture taken. No growth of microorganisms occurred. The canal was dressed with metaphen-eugenol and sealed with cement. The tooth has remained comfortable for the past month.

## DISCUSSION

The presence of yeasts has been reported in root canals. However when compared with the frequency of other microorganisms, particularly streptococci, in root canal cultures, one must conclude the finding of yeasts or yeast-like microorganisms is a rare or infrequent occurrence. Appleton (1), in his chapter

[1] Received for publication September 26, 1945.

on bacteria of the perapical area, mentions only Goadby as having reported on yeasts in this region. Goadby (2), however, made no attempt at identification of his so-called yeasts.

Microorganisms having the morphology of yeasts when studied by cultural methods are often found to possess a mycelium, a structure never found among the true yeasts. Such microorganisms are therefore designated as yeast-like. These yeast-like forms are often observed in body tissues only in the yeast cell form. Identification requires the determination of their cultural characteristics. The method of procedure is to pour fairly thick plates of corn meal agar and cut

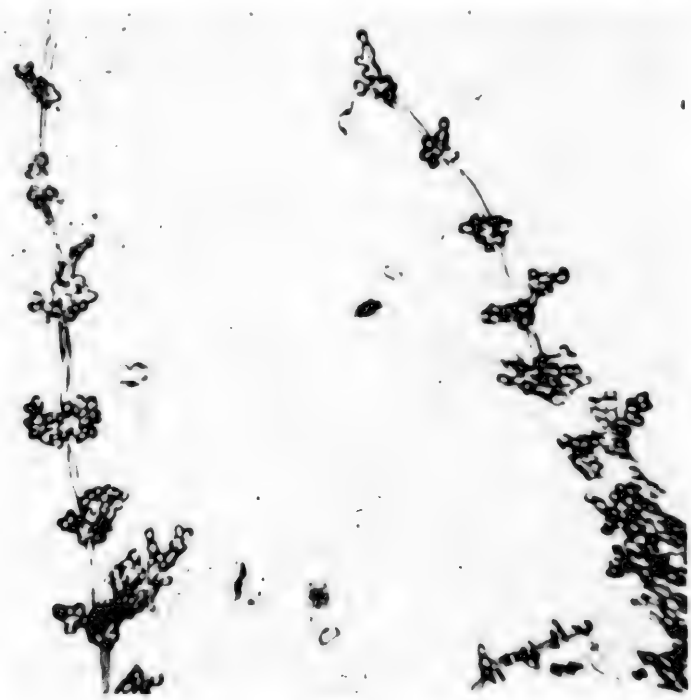

FIG. 1

deep streaks into the medium with a needle carrying the inoculum. After several days incubation the growth on the surface of the medium is found to consist only of yeast cells. The semi-anaerobic growth beneath the surface of the medium includes a mycelium to which is attached, at regular intervals, clusters of yeast-like cells, conidia (commonly called spores). These characteristics are observed in the genus *Candida*, formerly known as the *Monilia*. Species of this genus can be further differentiated by means of fermentation tests. The *Candida albicans* ferments dextrose and maltose with the production of acid and gas and saccharose with acid production only (3). The microorganism isolated from the 3 successive root canal cultures proved to be *Candida albicans* (*fig. 1*).

*Candida albicans* is an inhabitant of the normal mouth and throat (4). Benham (5) calls attention to the fact that *Candida albicans* can be obtained from the mouth even where there is no evidence that it is pathogenic; however, she questions whether such infestation is entirely harmless to the host. The *Candida albicans* is the incitant of thrush of the mouth and the vagina. It is found in infections of the lungs, in skin lesions, and has been reported as being present in an osteomyeletic lesion. Ingress to a root canal is generally via the open canal. The *Candida albicans* is resistant to penicillin. Hobby, Meyer and Chaffee (6) tested the activity of penicillin, in vitro, towards a number of microorganisms. They found that *Candida albicans* was one of the non-susceptible microorganisms. Tested by the plate cup method we observed that a concentration of penicillin of 10,000 units had no inhibitory action upon the *Candida albicans* strain isolated from the root canal.

It is interesting to note that the 3 cultures in which growth of the *Candida albicans* was obtained were taken prior to the appearance of the fistula. The disappearance of this microorganism after fistula formation probably was the result of improved drainage together with the phagocytoic activity of the inflammatory exudate about the tooth apex.

The importance of bacteriological examinations to determine the type of microorganism present in the root canal together with a knowledge of which microbes are susceptible to penicillin therapy is emphasized by our results. Penicillin resistant microorganisms must be controlled with other germicidal or antibiotic agents.

## SUMMARY

*Candida albicans* was isolated in 3 successive cultures from a root canal. This microorganism was resistant to penicillin therapy.

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# PHYSIOLOGICAL SIGNIFICANCE OF PHOSPHOLIPID IN HUMAN SALIVA

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Inquiry into the concentration of phospholipid is part of a comprehensive study on the role of the inorganic and organic constituents of the total oral secretion, the total saliva, begun over a decade ago. It was prompted by earlier investigation which purported the possibility of greater aberration for some of the salivary components than for their blood counterparts (Karshan, Krasnow and Krejci, 1931), (Krasnow, Oblatt and Hirschfeld, 1938) under certain conditions. As the work evolved, preliminary evaluation of the alcohol-ether soluble fraction indicated not only definitely determinable amounts, rather than a questionable trace (Youngburg, 1932), but also a wide range of values with striking group demarcation. Compilation of data was continued and to date comprises the findings on 207 cases representing both sexes varying in age, economic status, mode of living and conditions of health. The quantitative procedure and the general and specific distribution of values for particular groups will be detailed here.

## METHOD OF ANALYSIS

The uniformity of samples collected for analysis was carefully controlled: First with respect to the condition of the subject who should (a) have had no mishap, i.e. no incident which would upset the usual daily physiological state, for the preceding week, (b) submit a detailed record of the regular dietary taken during this 7 day interval, (c) have thoroughly cleaned teeth and mouth, and completely removed cosmetics from lips before retiring previous evening, (d) have enjoyed the habitual night's sleep, (e) not rinse mouth nor clean teeth, eat, drink nor smoke in the morning before collection, (f) plan an interval of 1½ to 2 hours including a 15 minute quiet period at the laboratory between rising and collection. Secondly with reference to the specimen, per se, which at the beginning consisted only of spontaneously flowing secretion until it was found that the 30 to 40 ml. required for the simultaneous determination of 6 constituents were more quickly secured by suction through a dental ejector, especially from very young children. The composition matched closely that of similar volumes obtained by the earlier procedure (Krasnow, Oblatt and Kaplan, 1936). Postabsorptive samples procured as described can be obtained at any age and are reproducible, presenting a consistency apparently characteristic of a definite biological plane. The analytical technique is patterned after that for blood

lipid phosphorus (Krasnow, Rosen and Porosowska, 1935). Certain adjustments have been made in standardizing each step to fit the contrastingly low content obtaining in saliva. Satisfying checks result when the method outlined below is adhered to:

Immediately after collection, 4 ml. saliva (non-homogeneity is insured by stirring the saliva vigorously for 1 to 2 minutes) are pipetted into a 70 ml. casserole, covered with Whatman #50 filter paper of 90 mm. diameter previously immersed in an alcohol-ether mixture (3:1) for 3 weeks, shaken 4 times daily, then dried and stored in covered containers. Evaporation is carried out over a boiling water bath just to dryness. When cool, 10 ml. (or sufficient to completely submerge the dried saliva) alcohol-ether (3:1) are added, boiled on the water bath for 30 to 45 seconds or until the residue can be loosened easily from the casserole with a stirring rod. Extraction is repeated by boiling 20 seconds. After cooling with casserole in tilted position, allowing the solids to sink, transfer is made to a 25 ml. glass stoppered volumetric flask. If the liquid is first poured and the residual solvent allowed to volatilize, the particles adhere to form a mass which can be moved into the flask without much difficulty. Then 2 ml. solvent is used to wash the casserole, poured into the flask and followed by a second portion of 3 ml. for reextracting by boiling whatever residue remained. The entire process of cold and hot washing is repeated. After bringing the contents of the flask to about 18 ml., it is digested for 30 seconds being constantly shaken while in the water bath at 100° C, cooled, made to volume and mixed energetically.

The filtrate, 20 ml. in a 70 ml. casserole, is evaporated to dryness over a water bath. To it are added 5 ml. of nitric acid (sp. gr. 1.42) and the dish rotated in such a manner that the dried extract is freed from the sides. Then 0.05 ml. sulphuric acid (sp. gr. 1.84), 1 ml. of a 1:1 mixture of saturated solutions of potassium and sodium nitrate and 1 ml. of saturated potassium chlorate solution are introduced. Digestion is carried out in a corrosion proof oven (Krasnow, Rosen and Porosowska, 1935) at 85° C for 20 hours. When the odor of fumes is no longer discernible, the resulting white crystalline product is dissolved in 2 ml. water, heated to boiling over a tiny flame and transferred to a 15 ml. conical centrifuge tube. This is repeated twice with 1 ml. water and allowed to cool.

Strychnine molybdate reagent (0.5 ml.) (Tisdall, 1922) is used to precipitate the phosphate, stirring at 10 minute intervals during the first half hour and allowing to stand undisturbed for another 30 minutes. After centrifuging for 3 minutes at about 2000 r.p.m., the supernatant fluid is decanted, drained 20 seconds and the mouth of the tube wiped with filter paper. The precipitate is washed twice with 2 ml. water, care being taken that its surface is disturbed only after the first washing. Each centrifugation should be followed by complete drainage of supernatant fluid to remove traces of the precipitant. The strychnine phosphomolybdate is dissolved in 0.5 ml. sodium hydroxide solution (0.25 M), diluted with 1.5 ml. water and transferred to a 10 ml. glass stoppered volumetric flask. The centrifuge tube is washed twice using 1 ml. water each time. Potassium ferrocyanide solution of 0.5 M concentration (2 ml.) and 1 ml. hydrochloric acid (sp. gr. 1.18) are consecutively introduced while mildly

agitating the flask. After 10 minutes, the mixture is made up to volume. Readings are carried out against 0.5 ml. of a standard solution containing 0.005 mg. phosphorus per 100 ml.

Duplicate analyses usually checked within the limits exemplified in these samples:

| Date | Case | Age | Sex | Phospholipid P Mg. / 100 ml. | |
|---|---|---|---|---|---|
| 6/25/35 | 43 Enso | 26 | F | 0.98 | 0.97 |
| 12/10/35 | 21 Cnsl | 7 | F | 0.08 | 0.09 |
| 12/10/35 | 20 Cnso | 22 | M | 0.52 | 0.48 |
| 6/ 2/36 | 59 Cnsl | 14 | M | 0.15 | 0.15 |
| 11/10/36 | 70 Cnso | 25 | F | 0.21 | 0.20 |
| 9/28/37 | 123 Cnsl | 9 | F | 0.19 | 0.17 |
| 1/ 4/38 | 145 Cnsl | 6 | F | 0.19 | 0.21 |
| 12/12/39 | 263 Enso | 40 | M | 0.37 | 0.37 |
| 3/26/40 | 291 Enso | 53 | M | 0.63 | 0.68 |
| 5/ 5/42 | 387 Insl | 3 | F | 0.11 | 0.11 |

## EXPERIMENTAL RESULTS

A. *General Distribution of Values.* The cases forming the basis of this report are detailed in Table I. They are aligned according to ascending magnitude of the salivary alcohol-ether soluble phosphorus.

Inspection of the figures reveals an almost continuous up-grade in content from 0.04 to 1.00 mg. per 100 ml., only 2 values falling beyond that range at 1.21 and 1.79. Visualizing percentage distribution plotted along the ordinate and the concentration interval along the abscissa, there results an asymmetric frequency polygon. Major skewness occurs beyond 0.40 while the rest of the graph approaches a normal bell shape with a peak between 0.13 and 0.16 mg.

B. *Apparent Variation in Concentration Distinguishing Normal and Abnormal Series.* When the cases are divided into 2 groups on a general health basis, one consisting of those adjudged normal by clinical and laboratory examinations and the remainder embraced in the second, the curves of *fig. 1* are obtained. This is deemed permissible because most of the ailments were considered mildly chronic with localized, generalized or mixed symptoms. Low values, for the most part below 0.13 mg. per 100 ml., predominate in individuals without abnormality whereas 80% of the analyses for the others rise above this level. The respective means are $0.119 \pm 0.011$ and $0.246 \pm 0.015$. Three decimal places are used in order that there be 2 significant figures in the standard error. Odds (Pearl, 1940) against the random occurrence of such a variation relative to the standard error are $4 \times 10^{41}$. This predicates the probability of a characteristic differential in mg. alcohol-ether soluble phosphorus per 100 ml. saliva setting off healthy persons from those affected with so-called low grade involvements. Except for a few rare instances, the conditions represented were mouth dryness, fatigue, underweight, obesity, constipation, colds, aphthous stomatitis, nervous irritability and restlessness, nail brittleness, gingivitis, tooth decay, dental erosion.

C. *Characteristic Differential Effect Enhanced When the Abnormal Cases Are Subgrouped.* Subclassification of the abnormal subjects into series based on

common dissimilarity narrows the spread of concentrations, thus segregating each and portraying an apparent dependence on physiologic status. *Fig. 2* exemplifies the degree of divergence from the normal Series I—Ins for 3 sample subgroups: Series II—Is, composed of individuals with systemic malfunctions, demonstrates how definitely discernible may be the difference concerning even small numbers of cases. There is not only a decreased incidence of contents below 0.13 mg. but also an increased percentage of those above it. Series

TABLE I

*Phospholipid Phosphorus in Total Postabsorptive Saliva, General Distribution of Values*

| DATE INTERVAL | AGE RANGE | INTERVAL | NUMBER OF CASES | PER CENT |
|---|---|---|---|---|
| | | *mg. per 100 ml.* | | |
| 4/25/39 | 36 | 0.00–0.04 | 1 | 0.5 |
| 12/ 3/35– 4/29/41 | 4–38 | 0.05–0.08 | 11 | 5.3 |
| 2/ 8/34– 5/ 5/42 | 3–43 | 0.09–0.12 | 36 | 17.4 |
| 10/29/35– 5/ 5/42 | 6–54 | 0.13–0.16 | 38 | 18.4 |
| 10/29/35– 5/ 5/42 | 6–33 | 0.17–0.20 | 28 | 13.5 |
| 10/15/35– 4/28/42 | 6–43 | 0.21–0.24 | 30 | 14.5 |
| 1/ 4/36– 4/28/42 | 7–43 | 0.25–0.28 | 23 | 11.1 |
| 10/27/36– 2/24/42 | 11–51 | 0.29–0.32 | 9 | 4.3 |
| 9/15/36– 4/15/41 | 14–31 | 0.33–0.36 | 5 | 2.4 |
| 12/10/35– 2/ 3/42 | 7–40 | 0.37–0.40 | 3 | 1.5 |
| 1/14/36–12/21/37 | 21–42 | 0.41–0.44 | 3 | 1.5 |
| 1/11/38 | 27 | 0.45–0.48 | 1 | 0.5 |
| 12/10/35– 3/ 4/41 | 22–66 | 0.49–0.52 | 4 | 2.0 |
| 6/ 2/36– 4/ 7/42 | 6–25 | 0.53–0.56 | 3 | 1.5 |
| 6/25/35 | 12 | 0.57–0.60 | 1 | 0.5 |
| 7/ 1/35– 9/28/37 | 32–35 | 0.61–0.64 | 2 | 1.0 |
| 3/26/40 | 53 | 0.65–0.68 | 1 | 0.5 |
| 6/ 2/36 | 38 | 0.69–0.72 | 1 | 0.5 |
| | | 0.73–0.76 | | |
| 6/25/40 | 31 | 0.77–0.80 | 1 | 0.5 |
| | | 0.81–0.92 | | |
| 6/25/35– 2/18/36 | 21–26 | 0.93–0.96 | 2 | 1.0 |
| 6/25/35 | 26 | 0.97–1.00 | 1 | 0.5 |
| 5/14/35 | 41 | 1.21 | 1 | 0.5 |
| 5/21/35 | 53 | 1.79 | 1 | 0.5 |
| Mean..... | | 0.24; Standard Error ±0.02 | | |

IV—Cs comprising persons suffering from general indisposition as well as active tooth decay evidences enhanced aberrations with further reduction in lower values accompanied by accentuated increase in higher ones. The frequency curve for Series III—Cns affected only with tooth decay displays a peak and span in positions intermediate between the corresponding points for the others.

Table II gives evidence which corroborates this trend toward differentiation between the normal and abnormal. Besides details defining the series already referred to, tabulations are included for 4 additional groups: Series V—Ens

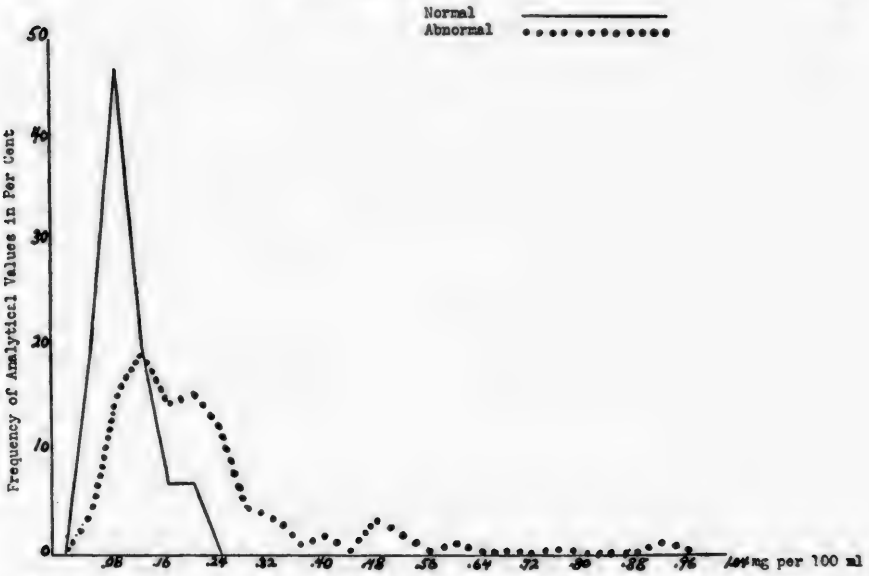


*Fig. 1.* Alcohol-ether soluble phosphorus in total postabsorptive saliva. Abnormal cases in toto compared with the normal.

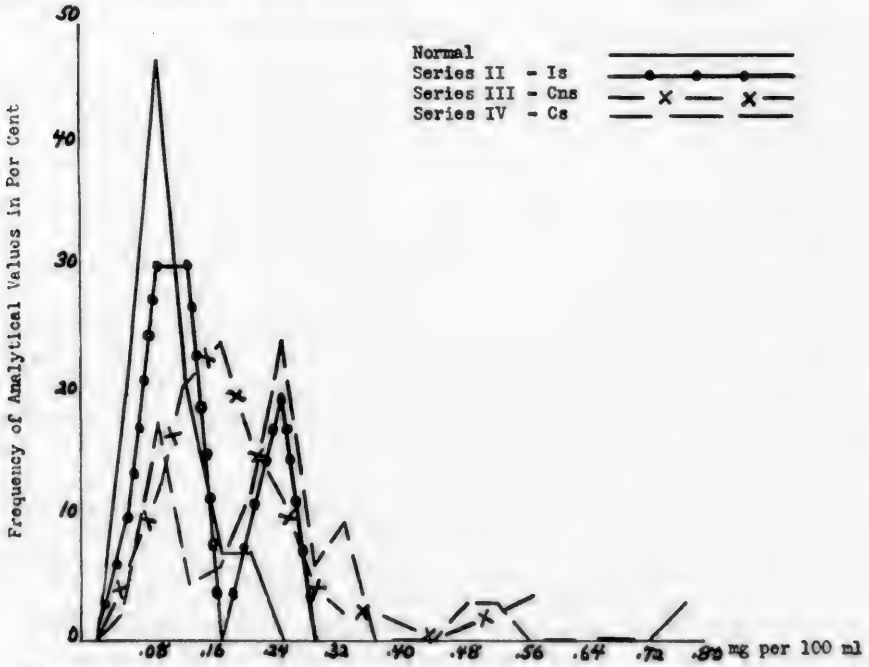


*Fig. 2.* Alcohol-ether soluble phosphorus in total postabsorptive saliva. Abnormal sub-groups representing different involvements compared with the normal.

representing individuals having no general disturbances but affected by dental erosion; series VI—Es suffering from systemic troubles as well as dental erosion; series VII—Ct, a composite of III and IV; series VIII—Et, a combination of V and VI.

The arithmetic mean of each abnormal subgroup is higher than that of the normal, 0.119 ± 0.011 mg. per 100 ml. saliva, thereby emphasizing the aberrance previously shown by the mean 0.246 ± 0.015 for all abnormal cases considered in toto. Statistical evaluation results in significant ratios, D/S.E. (Pearl, 1940) except possibly for Series II—Is. This class comprises few cases and consists of conditions varying least from the normal.

D. *Need for Classification According to Age Indicated. Greater Aberrance from the Normal Revealed at Higher Age Levels than at Lower ones.* The age levels of the several series listed heretofore are quite representative of those

TABLE II

*Phospholipid Phosphorus in Total Postabsorptive Saliva, Differences in Analyses between Normal and Abnormal Conditions*

| CASE TYPE | NUMBER OF CASES | AGE RANGE | MEAN | ODDS AGAINST CHANCE DIFFERENCES BETWEEN MEANS RELATIVE TO STANDARD ERROR |
|---|---|---|---|---|
| | | | *mg. per 100 ml.* | |
| Without abnormality | | | | |
| Series I—Ins. | 15 | 3–20 | 0.119 ± 0.011 | |
| With abnormality | | | | |
| Series II— Is. | 10 | 5–21 | 0.162 ± 0.023 | 10.22 |
| Series III—Cns. | 91 | 6–36 | 0.201 ± 0.012 | $1.744 \times 10^6$ |
| Series IV—Cs. | 34 | 4–35 | 0.242 ± 0.026 | 15,770 |
| Series V—Ens. | 55 | 13–66 | 0.328 ± 0.043 | $1.744 \times 10^6$ |
| Series VI—Es. | 12 | 13–57 | 0.317 ± 0.063 | 515.7 |
| Series VII—Ct. | 125 | 4–36 | 0.216 ± 0.01 | $5 \times 10^8$ |
| Series VIII—Et. | 67 | 13–66 | 0.325 ± 0.037 | $1.744 \times 10^6$ |

generally expected for the respective conditions entailed. Thus, comparatively few persons are privileged to enjoy complete health, freedom from any ailment, and then usually when young. Tooth decay is particularly widespread, affecting individuals from childhood to early adulthood. Contrarily, dental erosion appears characteristically in early adulthood and continues into late life. Only occasional exceptions are met.

Since the ages in the normal series I—Ins are lower and the range narrower than for the abnormal subgroups, inquiry was made into the relative levels of the analytical figures corresponding to lower and higher ages, i.e. below and above 20 years. The results are summarized in Table III.

First, it may be noted that once more the abnormal series, though delimited in age and number of cases, exhibit means elevated above the normal. Secondly, the figures obtaining in the b-series representing age levels over 20 years (indi-

TABLE III

*Phospholipid Phosphorus in Total Postabsorptive Saliva, Comparison of Aberrance from the Normal at Lower and Higher Age Levels*

| CASE TYPE | NUMBER OF CASES | AGE RANGE | MEAN | ODDS AGAINST CHANCE DIFFERENCES BETWEEN MEANS RELATIVE TO STANDARD ERROR |
|---|---|---|---|---|
| | | | *mg. per 100 ml.* | |
| Without abnormality | | | | |
| Series Ia—Insl. | 15 | 3–20 | 0.119 ± 0.011 | |
| With abnormality | | | | |
| Series IIa—Isl. | 9 | 5–20 | 0.170 ± 0.027 | 10.22 |
| Series IIIa—Cnsl. | 69 | 6–20 | 0.191 ± 0.01 | 413,263 |
| IIIb—Cnso. | 22 | 21–36 | 0.235 ± 0.015 | $5 \times 10^3$ |
| Series IVa—Csl. | 23 | 4–20 | 0.216 ± 0.03 | 307 |
| IVb—Cso. | 11 | 21–35 | 0.294 ± 0.058 | 287 |
| Series Va—Ensl. | 5 | 13–20 | 0.190 ± 0.035 | 16.41 |
| Vb—Enso. | 49 | 21–66 | 0.343 ± 0.048 | 845,320 |
| Series VIb—Eso. | 11 | 24–57 | 0.293 ± 0.065 | 121.1 |

TABLE IV

*Phospholipid phosphorus in total postabsorptive saliva*
*Increased concentration at higher ages*

| SERIES COMPARED | AGE RANGE | NUMBER OF CASES | MEAN | ODDS AGAINST CHANCE DIFFERENCES BETWEEN MEANS RELATIVE TO STANDARD ERROR |
|---|---|---|---|---|
| | | | *mg. per 100 ml.* | |
| Cnsl | 6–20 | 69 | 0.191 ±0.01 | 60 |
| Cnso | 21–36 | 22 | 0.235 ±0.015 | |
| Csl | 4–20 | 23 | 0.216 ±0.03 | 3.35 |
| Cso | 21–35 | 11 | 0.294 ±0.058 | |
| Ensl | 13–20 | 5 | 0.190 ±0.035 | 106.3 |
| Enso | 21–66 | 49 | 0.343 ±0.048 | |
| Cnssl | 4–20 | 92 | 0.197 ±0.025 | 26.99 |
| Cnsso | 21–36 | 33 | 0.255 ±0.010 | |
| Enssl | 13–20 | 6 | 0.253 ±0.035 | 6.48 |
| Ensso | 21–66 | 60 | 0.334 ±0.041 | |

cated by "o" in the class designation) are higher than those of lower age interval in the a-series (marked with "l"). Witness, 0.191 ± 0.010 and 0.235 ± 0.015 for series III a, b or 0.190 ± 0.035 and 0.343 ± 0.048 for series V a, b.

In the course of these investigations, it was found that return to health was associated with a change in the salivary alcohol-ether soluble phosphorus from aberrant values toward the normal, 0.119. This followed irrespective of age level, thus indicating the possiblility of employing 0.119 ± 0.011 as reference mean to compute the comparative significance of the findings in Table III. The odds are great enough to give probable statistical meaning to the means of series III a and b, IV a and b, and V b. Those for series II a, V a and VI b are not so definite and call for analysis of additional cases, notwithstanding that their distinctly elevated means portend some degree of certainty.

Further review of the data in Table III presents the possibility of comparing the salivary alcohol-ether soluble phosphorus content obtained for the older and younger subdivisions of series III, IV and V. The increments may then be viewed as variations specific to difference in age level. This is done in Table IV. The critical ratios D/S.E. are lower than those in Table III. They indicate that aberrances due to age alone although they may exist are in all probability less marked than those brought on by disease. The figures therefore bear out general biological tendencies.

## SUMMARY

1. Phospholipid phosphorus is present in human saliva in estimable amounts. Thus far determinations have been made on 207 persons variously conditioned.

2. Low values predominate in individuals adjudged normal by clinical and laboratory examinations.

3. Higher concentrations obtain in those above 20 years than at younger ages. The differences are less than those effected by disease and therefore, bear out general biological tendencies.

4. Physiological malfunctions, even of mild types are associated with contents above the normal average, 0.119 ± 0.011 mg. per 100 ml. saliva—exemplified in 0.191 ± 0.01, 0.294 ± 0.058, 0.343 ± 0.048. Such analyses may serve as diagnostic aids in establishing early deviation from health and so would be instrumental in helping to maintain optimal well-being.

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*13. New Haven*—Discontinued 1940.

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[3] Members of the Materials Group may and in most instances do belong to Sections.

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Total membership as of Dec. 1, 1945—633.

## III. BOOKS RECEIVED, 1945

Blauch, Lloyd E. and Associates, *Teaching in Colleges and Universities* (American Association of Dental Schools, Indianapolis 2, Indiana: 1945) pp. 341.

Darlington, C. G., Wilson, G. W., Waldron, C. W., Tylman, S. D., Moore, G. R., and Miller, H. C. *The 1944 Year Book of Dentistry* (Chicago, Year Book Publishers: 1944) pp. 701.

Prinz, Hermann, Rickert, U. Garfield, and Dobbs, Edward C., *Pharmacology and Dental Therapeutics*, 9th Ed. (St. Louis, The C. V. Mosby Company: 1945) pp. 507.

Prinz, Hermann, *Dental Chronology* (Philadelphia, Lea and Febiger: 1945) pp. 189.

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[1] Abbreviations used: I. A. D. R.—International Association for Dental Research; J. D. R.—Journal of Dental Research.

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## INTERNATIONAL ASSOCIATION FOR DENTAL RESEARCH

*Organized:* New York City, Dec. 10, 1920. Of those at the meeting of organization, the following remain active members: Adolph Berger, Theodor Blum, G. W. Clapp, H. S. Dunning, W. J. Gies, R. G. Hutchinson, Jr.; T. P. Hyatt, Milo Hellman, A. H. Merritt, B. B. Palmer, P. R. Stillman, L. M. Waugh.

*General Meetings* have been held on this schedule: (1) New York, Dec. 21, '22. (2) Chicago, Mar. 7, '24. (3) Chicago, Mar. 20, '25. (4) Chicago, Mar. 26, '26. (5) New York, Apr. 19, '27. (6) Washington, Mar. 25–28, '28. (7) Chicago, Mar. 23–24, '29. (8) Toronto, Mar. 24–26, '30. (9) Memphis, Mar. 21–22, '31. (10) Columbus, Mar. 19–20, '32. (11) Chicago, Mar. 18–19, '33; adjourned executive session, New York, May 25, '33. (12) Chicago, Mar. 17–18, '34. (13) Chicago, Mar. 16–17, '35. (14) Louisville, Mar. 14–15, '36. (15) Baltimore, Mar. 13–14, '37. (16) Minneapolis, Mar. 12–13, '38. (17) Cleveland, Mar. 18–19, '39. (18) Philadelphia, Mar. 13–14, '40. (19) St. Louis, Mar. 15–16, '41. (20) New York, Mar. 14–15, '42. (21) Chicago, Mar. 13–15, '43. (22) Chicago, Mar. 18–19, '44.

*Objects (Const., Art. II):* . . . "(a) To promote broadly the advancement of active research in all branches of dental science and in related phases of the sciences that contribute directly to the development of dentistry, and which add to the knowledge of the mouth and teeth and of their relations to the body as a whole; . . . (b) to encourage and facilitate coöperative effort and achievement by, and mutual helpfulness among, investigators in all nations in every division of stomatology; (c) to the end, particularly, that dentistry may render cumulatively more perfect service to humanity." (The Association has been using "dentistry" and "stomatology" as synonyms.)

*Membership:* total (Dec. 1, 1945), 633. *Eligibility (Const., Art. 14, Sec. 1).*— "Any person who has conducted, and published an account of, a meritorious original investigation in dental science, or in any of the sciences contributory to stomatology, shall be eligible to membership in this Association, providing such person conforms to the recognized standards of professional ethics." *Election.*— New members may be elected *only at general meetings of the Association.* Membership in a section is secondary to membership in the Association as a whole. Removal of members from one geographic center to another does not affect their membership in the Association.

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## INTERNATIONAL ASSOCIATION FOR DENTAL RESEARCH

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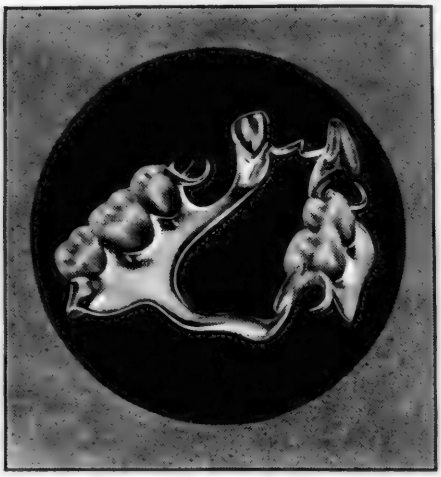

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